FOREST PRODUCTS RESEARCH 1951

DEPARTMENT OF SCIENTIFIC
AND INDUSTRIAL RESEARCH

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF THE FOREST PRODUCTS RESEARCH BOARD

WITH THE REPORT OF
THE DIRECTOR OF FOREST PRODUCTS RESEARCH

FOR THE YEAR
1951

LONDON: HER MAJESTY'S STATIONERY OFFICE
1952

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1951

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[1] Until 31st March, 1951.
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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE YEAR 1951

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Forest Products Research Board, beg leave to present our report for the year ending December 31st 1951.

The year in retrospect has brought no change in the factors which mould the Laboratory's policy and determine the scope and direction of its effort. Notwithstanding some easement in the timber situation, the need remains to test and assess every sort of timber which may be useable either in its own right or as a substitute for the traditional ones. We have, therefore, to report that the testing of new Colonial species continues without intermission, as the major project, and that the data obtained from the tests are being made available to industry without delay.

We have also to report that the volume of advisory work and its associated short-term investigations have remained substantially that of the two previous years, and that the pattern of the enquiries and their distribution among the various sections of the Laboratory remain in effect unchanged. We have, however, been pleased to see the development of a trend in the type of enquiry which is a welcome one, namely, that advice is being increasingly sought before industrial projects are started rather than after they have gone wrong. This denotes an increasing acceptance on the part of industry of the practical value for application of the data scientifically obtained. Implicit also is the gratifying fact that the work which the Laboratory is doing is in very close relation to the requirements of industry.

These two commitments, the advisory work and the investigations on tropical timbers, still consume most of the available time of the staff, and a state of unbalance still exists between the day-to-day and routine tasks and the longer term research projects. We are aware that under present circumstances there is little chance of amelioration of this situation, but we feel that nevertheless the need for increasing the proportion of basic research should never be lost sight of.

From the Director's report may be gathered an idea of the volume and scope of the year's advisory work. With the exception of the Furniture Development Council, still in the early stages of development, no research association exists in the timber industry, and the Laboratory is still the only institution to which industry can turn for the solution of its problems. The remarkable diversity of subjects which are dealt with in the daily course of the work bears witness alike to the widespread industrial clientele of the Laboratory and the versatility of its specialist officers.

The work of the various sections is reviewed in the Director's report and much of it requires no express mention here. There are, however, some noteworthy aspects of the year's work to which we would draw attention.

TIMBER STRUCTURES

The new Structures Laboratory has been completed and is now in use. This building can accommodate a full-scale roof as well as single members, such as trusses, up to 70 ft. long and 18ft. high. A variety of tests has already been carried out, including a large 57 ft. industrial truss. Timber has a very low shearing strength along the grain and joints in load-bearing structures require careful designing. The important Timber Mechanics project on the strength of joints of various types (nailed, bolted, glued, etc) can, in the new laboratory, be carried forward to tests on the complete structures in which they are incorporated.

WOODWORKING RESEARCH

The Woodworking Laboratory has also been occupied, and much of its machinery is already installed. Until recently some of the woodworking studies could only be made by using the machinery employed in routine production work. In the new building the research machines can be used without interfering with the ordinary woodworking production for the rest of the Laboratory.

During the year the theoretical study of the inter-relation of factors affecting the operation of sawing has been extended, and on the practical side further direct observations have been made on chip formation and on the interaction between the cutting edge and the wood.

IDENTIFICATION OF TIMBERS

After twelve years of continuous practical experience the lens key to the hardwoods has been brought up-to-date, and the revised edition is in the press. This key, which is based on a perforated card system, enables the identification of the commercial hardwoods to be undertaken without the use of the microscope, and it can be expanded as new timbers appear. A companion atlas of photographs is also in course of publication. These volumes should go far towards enabling the non-technical worker to undertake his own identifications.

WOOD CHEMISTRY

The year has seen the conclusion of a long and successful collaborative research with Professor E. L. Hirst on the constitution of the wood starches. This work, which began some twenty years ago with the search by the Chemistry Section for methods of isolating the wood-starches in pure granular form, has after many vicissitudes now been successfully concluded in a joint communication made this autumn.

The experimental plant for the manufacture of fibreboard from tropical timbers is now in operation, and it has already been established that good quality boards can be made from wallaba, a timber from British Guiana. There are now reasonable grounds to believe that the tropical timbers will prove suitable for the manufacture of fibreboards.

MYCOLOGICAL STUDIES

Following the recognition of an unusual type of fungal decay in the timbers of water-cooling towers, it has been found that the fungi concerned can cause their characteristic breakdown of wood in many other situations, some of them of economic importance. A new field of investigation has been thrown open, which is likely to present some very interesting physiological problems.

From the accumulation of evidence it can now be confirmed that the decay of timbers in small wooden craft, to which we have drawn attention in previous reports, is a matter of widespread and serious importance. A meeting with the boat building industry, owners and others interested has been arranged to decide how best to secure dissemination of information on the causes and cure of the decay and to bring the resources of the Laboratory to bear on the problem.

ENTOMOLOGICAL RESEARCH

Despite the extensive advisory work on all the wood-destroying insects, it has been possible this year to devote more time to research on the biology of the furniture beetle, and very interesting additions have been made to our knowledge of its nutrition and of the laying and hatching of the eggs. Also, as material from areas infested by the house longhorn beetle has become available, it has been possible to make some investigations into the egg-laying and hatching of this potentially serious pest. Close contact is being maintained with the local authorities of areas where outbreaks have recently been discovered.

The evaluation of promising methods of destruction of all the wood-boring insects continues.

WOOD BENDING

We have to report a very full and fruitful year's work not only in the increasingly important aid given in specific industrial problems, but also in the production of new techniques. We would especially mention the further development of the method of bending tropical timbers and the recently patented process for the production of small-radius bends for the corners of wardrobes, radio cabinets and the like, which have already evoked gratifying interest from the trade.

TROPICAL TESTING

The behaviour of adhesives and of glued assemblies under tropical conditions is a matter of increasing importance to British industry. The storage rooms of the recently completed tropical testing house will now enable the manufacturer to assess his products both in respect of their storage qualities and their performance under the cyclical conditions of either the wet or the dry tropics. The work room, in which tropical solar effects can be simulated will enable tests to be made of the actual application of adhesives under selected conditions. Much of the Laboratory's own testing work in the house will be complementary to that in the recently extended scheme on weathering and durability in operation at Kano and Port Harcourt in Nigeria.

ADVISORY PANELS

Once again we wish to record our thanks to the visiting members of the three advisory panels for their expert services so freely given. The first of these panels, the Adhesive Makers' Panel, although an informal body, has with the passage of time become recognized by both manufacturers and users as the authoritative body on matters affecting the use of adhesives in plywood production. The others, the Plywood Research Panel and the Radio Frequency Panel, have already rendered invaluable service to the Laboratory in the moulding of the respective programmes of research.

THE GENERAL WORK

From our consideration of the reports on the work of the various sections

and of our inspection and discussion of the work in progress, we are pleased to report to your Lordships a very satisfactory year's work.

MR. W. G. CAMPBELL

The Laboratory has sustained a serious loss by the sudden death in November of Mr. W. G. Campbell, shortly after his return from conferences in America, where he had presented an account of recent research work. One of the earliest members of the staff, he had guided the work of the Chemistry Section since its inception, and its high reputation of twenty-five years is a fitting monument to his work.

MEMBERSHIP OF THE BOARD

In March, 1951 Mr. Eric Bird and Mr. A. D. Wood retired from the Board on completion of their terms of office. We wish to record our appreciation of their services during the period. We have welcomed Professor W. T. Astbury, Mr. David Booth, and Mr. Paul Williams who have joined the Board during the year.

E. J. SALISBURY,
Chairman

March, 1952.

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE YEAR 1951

INTRODUCTION

The work of the year 1951, like that of its immediate predecessors, has been largely influenced by the national timber situation and by the high proportion of staff time absorbed by short-term investigations and advisory work for industry. These commitments, together with the major project of testing and evaluation of new Colonial timbers, continue to restrict the time which can be spared for work on more basic investigations, many of which are carried on intermittently as circumstances permit. Present day limitations of staff make unlikely any immediate improvement in this respect.

In addition to the assistance given in the solution of specific problems, co-operative work with industry, public bodies and with other government departments improves and increases, both in established fields of work and through new contacts. In particular, close collaboration has been maintained with the Furniture Development Council, whose recently formed experimental section and technical advisory service are now rapidly expanding.

GENERAL

STAFF

It is with great regret that I have to record the death of Mr. W. G. Campbell, the Officer-in-Charge of the Chemistry Section. An honours graduate in both Chemistry and Botany, Campbell was particularly fitted for research in Wood Chemistry, and the successful and noteworthy work of his Section in the hemicelluloses and in the wood starches are to his credit; and new and very promising work on lignin has been halted by his sudden death. Over the twenty-five years of his service he had acquired a unique and encyclopaedic knowledge of wood chemistry as applied to industrial problems which made him invaluable in our advisory work. With his passing the Laboratory has lost a far-seeing and able leader of research and his colleagues a valued friend.

No other significant staff changes have occurred in the course of the year. Limitation of complement and the present standstill on recruitment postpone the restoration of balance between the various grades, and the weakness in junior staff is not only a matter of immediate embarrassment, but, taken with the restriction on fundamental work is also of concern for the future since the younger members must perforce be utilized in the advisory work to the exclusion of their training in the art of research. This is serious in timber technology, where the work requires specialization over long periods before research itself is undertaken; it is particularly so for the Laboratory, where there is already a wide age gap between the senior specialist staff—the original recruits of 25 years ago—and the newer members.

BUILDINGS AND EQUIPMENT

The new Timber Structures and Woodworking laboratories and the extensions to the woodworking and carpenters shops have been completed and all are in occupation.

The addition to the Seasoning Section has now been almost completed, and its sub-section of Wood Bending should move over from its temporary premises early in 1952.

The conversion of the old " Dry Rot House " to a laboratory for the tropical testing of laminates and adhesives has been completed, and a note on its functions appears on page 25 of this report.

TOURS

In March, 1951, the Officer-in-Charge of Composite Wood Section was invited by the United Africa Company to visit the plywood mill at Sapele, Nigeria, and they generously included in the tour the Tropical Testing Establishment of the Ministry of Supply at Port Harcourt and Kaño, where collaborative work on the durability of plywood glues is in progress. Every opportunity was given at Sapele for studying the special problems of plywood manufacture under tropical conditions, and at Port Harcourt, discussions with the Superintendent led to an extension of the glue durability experiments as described in the section on the " Properties of Adhesives " (page 19).

In August, 1951, a senior member of Timber Mechanics Section attended the Second F.A.O. Conference on Mechanical Wood Technology held at Igls, in Austria, and later made visits to Swiss manufacturers of testing apparatus. A note on the proceedings of the Conference appears on page 15 of this report.

A senior entomologist represented the Laboratory at the Ninth International Congress of Entomology at Amsterdam, also in August, to present a paper on the Laboratory's work. He took the opportunity of visiting research institutions and commercial firms in the Netherlands to collect information of interest.

The Officer-in-Charge of Chemistry Section spent about three months in the United States and Canada between July and October. His tour included attendance at several conferences on chemistry, at which he presented papers on the current work of the Laboratory. He later visited the Forest Products Laboratory at Madison, as well as a number of industrial firms, to gather information concerning the manufacture of fibreboard from hardwoods. A note on the tour appears on page 48 of this report.

ADVISORY PANELS

The three informal advisory panels—the Adhesive Makers' Panel, the Plywood Research Panel and the Radio Frequency Panel—have held their usual meetings at the Laboratory or in London. Thanks are again accorded to those industrial associations and government departments who have so freely placed at our disposal members of the highest technical ability for the purpose of discussing the improvements of the research programme.

PUBLICATIONS AND RECORDS

During the year Bulletin No. 24 " The Protection of Buildings and Timber against Termites " and the booklet " Hardwoods for Building and General Purposes " were issued through H.M. Stationery Office. The Bulletin on termites was prepared with the collaboration of the Building Research Station,

and provides information for those engaged in building in the tropics. The booklet on hardwoods deals with the more important characteristics of a large number of species recently imported into this country, many of which may be substituted for softwood for building work generally. Information on the properties of thirteen tropical species now coming into this country was issued in individual leaflets for distribution to firms handling the various timbers.

A supplement to Leaflet No. 45 " The Steam Bending Properties of Various Timbers " has been published, dealing with some twenty additional species, and the manual on kiln-seasoning for the use of kiln operators has been completed and is ready for printing.

Particulars of the year's publications are listed in Appendix II, together with the thirty-four papers published in the scientific and technical press. In addition twenty-five reports were prepared for limited distribution.

THE ADVISORY SERVICE

The number of enquiries answered by letter or report during the year was 5,876. This figure takes no account of the substantial amount of staff time occupied by visitors, telephone enquiries and other forms of advisory service, but it serves as a useful criterion of the volume of the service rendered yearly. This year the number of replies by letter shows a slight fall and lies between the figures for 1949 (5,621) and 1950 (5,934). It would be premature to draw any conclusions from the flattening of the curve during the last three years, or to assume that anything like complete contact with industry has been made. Moreover, at this level of enquiries the burden of advisory work is still as much as the staff of the Laboratory can comfortably bear, and the need for further recruitment is as urgent as ever if an adequate research programme is to be carried on. Some amelioration may be expected as industry becomes able to solve for itself more of its technical problems. A review of the year's advisory service shows that in many instances the information or advice required was not readily available to the general public, and the preparation of replies often involved expert consideration if not special investigation. On the other hand a considerable proportion of the enquiries to some sections of the Laboratory might have been answered by the inquirers having recourse to published information.

The number of leaflets for routine replies on dry rot, furniture beetle, etc., issued during the year was 43,800, excluding those distributed at exhibitions.

THE PROGRAMME OF RESEARCH

WOOD STRUCTURE

Research in the Wood Structure Section continues to be largely directed towards acquiring the basic data necessary for identifying timbers and assessing their economic importance, and the main lines of the work have been determined by demands for information on timbers coming into the country. Studies of individual timbers and of groups of species have continued, but owing to the large number of timbers involved and the continual changes in the supply position, with the resultant wide range of enquiries which must be expeditiously dealt with, the work has necessarily been extensive rather than intensive, and the cumulative results of the past year cannot easily be summarized in terms of scientific achievement. Their value to industry at this time of unsettled timber

supplies is reflected in the advisory work of the Section. There has been a continuous stream of requests for information on the general character and suitability of new or unusual timbers offered to importers, manufacturers, builders, architects, etc., and for advice on alternatives to standard timbers in short supply.

It is noteworthy that useful timbers of potential interest for export are still being discovered in certain parts of the world where the local forest resources have recently been developed. Overseas shippers have sought the advice of the Laboratory on the market prospects of several practically unknown timbers.

Enquiries frequently involve the identification of timbers and nearly 1,500 speciments have been identified in the course of the year. There has been an unusually large number of instances of inferior timbers being included in parcels of the more popular kinds.

Pieces of timber which have failed in service are submitted to the Laboratory for an opinion on the cause of the failure, and in some their abnormal behaviour has been traced to natural defects such as brittleheart, irregular grain and tension wood, and in others to the use of an unsuitable grade or species of timber.

Other enquiries have been concerned with such diverse subjects as methods of identification, industrial dermatitis attributed to timber, and wooden objects of archaeological interest. Overseas enquiries have been received from Belgium, California, Mexico, South Africa and New Zealand and have also included requests for advice on the local utilization and marketing of secondary timbers in Gambia, Tanganyika, Sierra Leone and Sarawak.

The number of enquiries dealt with by written reply from the Wood Structure Section amounted to 640.

Hardwoods for Building and General Purposes

It is the essence of timber economy that the supplies available at any one time should be used to the best advantage. A feature of the timber situation in recent years has been a shortage of many of the traditional timbers of commerce. This deficiency has been offset to some extent by comparatively good supplies of the less familiar and usually less popular varieties, mainly tropical hardwoods, and in order to conserve the limited supplies of softwood for essential purposes it has been the policy to encourage the use of hardwood in place of softwood wherever practicable. The classified list of hardwoods capable of being used in place of softwoods, which was originally drawn up as an appendix to the Ministry of Works Economy Memorandum, " Use of Timber in all Building Work ", has been revised and extended to include most of the general-purpose, licence-free hardwoods likely to be offered to builders, contractors and manufacturers. This document has now been issued as a separate publication[1].

Collection of Timber Specimens

Additions to the reference collection of timbers included nearly six hundred specimens, principally from Australia and India, presented by the Imperial Institute, and smaller collections from British Guiana, Sierra Leone, Tanganyika, the Belgian Congo, Indonesia, and the Philippine Islands. The number of specimens in the catalogue now exceeds twenty thousand. In addition to the hand specimens in the working collection, a representative collection of larger (18-in.) panels of commercial timbers has been built up and is permanently

[1] *Hardwoods for Building and General Purposes*, London, H.M.S.O., 1951.

displayed in the corridors of the administrative building. These specimens have been in demand for demonstrating to visitors and for exhibitions. Grateful acknowledgement is made to the Director, Imperial Forestry Institute, Oxford, and to those timber importers and merchants who have presented material for exhibit specimens.

Nearly six thousand small hand specimens of timber have been distributed during the year and a collection of over three thousand duplicate microscope slides has been presented to the Timber Development Association.

Keys to Hardwoods

A revised edition[1] of the Laboratory's lens key to hardwoods, based on the perforated card system has been prepared for publication. A limited edition of this key was issued in 1940, since when the method has been widely used for identification keys and has proved to be of practical worth. More recently the growth of technical education in the timber trade and the remarkable increase in the number of timbers on the market have stimulated interest in identification and have created a keen demand for a systematic method of naming timbers without recourse to microscopic examination. In its present form the key should go some way to facilitate the identification of timber by workers in forest, timber yard, factory and office, provided they have acquired a sound knowledge of elementary wood structure.

There has been considerable delay in preparing the key for publication, partly owing to the large number of unfamiliar timbers which have been imported in recent years and the desirability of including as many of these as possible. Most of the recent timbers have now been added and the key covers practically all the commercial hardwoods likely to be found in this country at the present time.

An essential feature of the card key is that it can be expanded indefinitely by the inclusion of additional species. It can be readily adapted for local use by foresters and others who are concerned with the timbers of a particular region. The operation of the key is shown in Plate 1.

A supplementary volume consisting of low-power photomicrographs of the timbers included in the lens key has also been prepared. It is intended to issue this as a separate publication[2]

For the routine identification of timbers submitted to the Laboratory the key based on microscopic features is in constant use, and the task of keeping it up-to-date involves the systematic examination of additional species as required.

Physiology of Heartwood Formation

It is now clear that the girdling technique worked out for interrupting the flow of sap does not appreciably affect the vitality of the tree and no serious trouble from fungal infection of the sawn girdle has occurred. The changes which take place in oak during normal heartwood formation are shown in Plate 2. The effects produced by the girdling are of physiological interest but are so far disappointing in that no widespread increase in the proportion of fully developed heartwood has yet occurred. There is some evidence that the sequence of events in the transformation from sapwood to heartwood differs in oak and larch.

[1] Identification of Hardwoods: A Lens Key, *Bull. For. Prod. Res. Lond.*, No. 25. (*In the press*).

[2] An Atlas of End-grain Photomicrographs for the Identification of Hardwoods. *Bull. For. Prod. Res. Lond.*, No. 26. (*In preparation.*)

In a supplementary experiment a bark girdle was cut at the top of the bole in addition to the main girdle at the base with the object of preventing any replenishment of the food reserves in the trunk by fresh supplies from the crown. This has caused a much more marked fall in the starch content of the trunk but appears to have prevented the formation of healing callus. This experiment, together with other evidence, indicates that callus formation, upon which the present experimental technique depends, is governed by substances derived from the active leafy crown and that these are not ordinary food substances such as starch and sugar.

No new trees have been girdled this season; observations are being continued on borings taken periodically from the 8 trees previously girdled.

SEASONING

Kilns and Kiln-seasoning

During the course of the year, the large seasoning kilns have been used for the drying of opepe and ramin to obtain information on their seasoning properties, of afzelia for vat making, and of agba, Corsican pine, and beech, to provide experimental material for use within the Laboratory. In the smaller kilns, experimental loads of binuang, ramin, African mahogany, kokrodua, brown sterculia and kurokai have been dried. Of these, the kokrodua proved to be the least refractory in that it seasoned readily and well with virtually no degrade. The binuang and brown sterculia both exhibited inferior seasoning proprieties and tended to split and distort badly.

A series of preliminary tests has been started in co-operation with a firm of broom-head manufacturers to determine whether birch poles can be satisfactorily kiln-seasoned. Tests to date have shown that birch poles can be suitably dried, but that the process would probably prove to be uneconomical. Much more promising results were obtained by kiln-seasoning the roughly shaped short lengths after a preliminary treatment in a saturated solution of urea. Further tests on these lines are in progress.

Small parcels of afzelia, makoré and muninga have been seasoned at the request of the Admiralty Compass Observatory at Slough to determine whether the kiln-dried material would prove suitable for the manufacture of compass binnacles.

Kiln Schedules

Tests on the so-called " stress schedule " method of seasoning, which, in general, involves the more rapid lowering of humidity and the use of much higher temperatures during the final stages of the run than hitherto, have been carried out on a consignment of English oak.

The indications from these tests were that, although the drying time of oak can be considerably shortened, this can only be done at the expense of an increase in splitting and checking. The commercial significance of this additional degrade is difficult to assess but, for certain purposes, it would probably be regarded as relatively unimportant.

Veneer Drying

Experiments have been undertaken in co-operation with a commercial firm to determine whether sliced decorative veneers can be dried in packs of $\frac{1}{2}$ in. and 1 in. in thickness in a standard-type seasoning kiln. The veneers were of guarea

and sapele cut to a thickness of 0.6 mm. and were supplied green straight from the slicer. They were formed into packs and piled with 1-in. sticks at 8-in. intervals in the manner normally adopted for the piling of solid timber.

The tests demonstrated that such material could, in fact, be dried quite satisfactorily and to a reasonably uniform final moisture content. It is, however, possible that, with wider sheets, or with species which shrink more than guarea or sapele, the restraint imposed by this method of piling would cause splits to develop.

The 1-in. packs were dried from green to 15 per cent moisture content in 122 hours, which was a period about 3 times as long as that taken to season loads made up of veneer packs $\frac{1}{2}$ in. in thickness. In a stack of given dimensions, the quantity of veneer that can be accommodated is increased only by 50 per cent by increasing the pack thickness from $\frac{1}{2}$ in. to 1 in., so that the output from a kiln in a given time would be only approximately one-half of that which could be obtained with $\frac{1}{2}$-in. packs. Against this must be set the fact that slightly more labour is involved in loading and unloading the thinner packs.

Radio Frequency Drying

No further experiments on radio frequency drying have been undertaken. A detailed report covering the work of the last three years has been prepared.

Seasoning in Superheated Steam

Interest has been shown recently in the method of seasoning in superheated steam as advocated by certain firms in Germany. In this method, the wood is subjected to steam at atmospheric pressure but at temperatures above the boiling point of water. A kiln of a pattern similar to those used for the more orthodox method of seasoning may be employed, but with additional heating to provide for the superheating of the steam which is here the heating medium. An augmented system of fans is also desirable to provide for a very rapid movement of the superheated steam through the pile of timber. In order to investigate the possibilities of this drying method, a small experimental chamber has been devised and built in which the superheating is accomplished by means of electrical heating elements and some test runs have been made. Samples of beech have been dried in superheated steam at various temperatures, but in every instance the shrinkage that occurred was high, and considerable surface splitting took place. Other woods such as African mahogany, obeche, and gaboon have been tested, and, although more promising results were obtained on the " soft-hardwoods " than on beech, shrinkage and casehardening were usually greater than that brought about by the normal kiln-drying schedules. An increase in shrinkage is usually associated with increased distortion, and timbers that have a tendency to collapse on drying would certainly be expected to do so when subjected to such high temperature treatments.

Drying by Boiling in Oil

Boiling in oil has sometimes been put forward as being a possible method of seasoning timber. A few small exploratory tests were made during the year to examine the effect of drying oak and beech by this method. The results showed that both species can be dried rapidly in this way, but that they shrink abnormally and are prone to suffer serious degrade in the process. The samples of oak were all so badly split, honeycombed and collapsed as to be virtually

useless. The damage to the beech was less serious, and it is perhaps possible that in certain special instances small pieces of this and of other relatively permeable woods could be dried satisfactorily by boiling in oil but, as was in fact expected, for general application the method would not seem to merit serious consideration.

Air-drying

The $4\frac{1}{2}$-in. quarter-sawn oak similar to the material kiln-dried for use in the rebuilding of the House of Commons was examined in June of this year. This had been put out for air-seasoning in November, 1949, and, at the time of examination was found to have attained an average moisture content of 35 per cent. Distribution tests showed, however, that most of the planks still had a core moisture content of between 50 and 60 per cent. Very considerable splitting had developed on the flat-sawn edges of the planks.

Flooring Tests

Considerable interest has been aroused recently in the problems connected with the sub-floor or panel heating of rooms in which strip or block flooring has been installed. The main problem arises from the fact that such systems cause the wood floors to attain an unusually low moisture content in winter when the heating system is in operation, whereas, in summer, when the heat is off, the moisture content will tend to be much as in other buildings. This means that the " movement " of the floor will be greater than is normal with the more orthodox forms of heating. The effects of movement are liable to be more serious on a block floor than on strips which are nailed in position, and most of the block floors which have so far been laid over sub-floor heating have been of teak or some equally stable timber. A teak block floor, laid by a firm of flooring contractors at a moisture content of 9 per cent in the assembly hall of a school in Bristol has been kept under observation throughout the year, and, to date, no trouble has developed.

A preliminary experiment designed to yield information on the moisture content and dimensional changes which would occur in strip floors laid over heating pipes has been put in hand. Sample panels of 4 different species, viz. gurjun, teak, maple (slash-sawn), and beech (quartered), have been assembled in the form of a box into which was introduced an electric tubular heater. The initial moisture content of the teak was 8 per cent and of the other species 10 per cent. The conditions likely to be encountered in practice were roughly simulated by placing the assembly in air conditioned to 45 per cent humidity and maintaining by means of the heater a temperature on the surface of the strips some 13°F. higher than that of the surrounding air. When equilibrium was established, the gaps between the strips were measured, and the assembly was then placed in air at a humidity of 75 per cent with no additional heating from within. Finally the assembly was subjected once more to the same air temperature and humidity conditions as formerly.

The results obtained are indicated in Table 1.

Although it cannot be said that the conditions of service were exactly reproduced in these accelerated tests, the results would nevertheless suggest that wood floors might be expected on occasions to dry to as low a moisture content as 5-6 per cent. It is interesting to note that after the second exposure to the dry conditions an increase in the width of gap was recorded in every instance.

This increase was in part attributable to the compressive " sets " induced during the intermediate exposure of the strips to the relatively high humidity conditions.

TABLE 1

Species	Average gap after 1st exposure in air at 45 per cent humidity (in.)	Average gap after 2nd exposure in air at 45 per cent humidity (in.)	Final average moisture content (%)
Quartered beech	0.020	0.030	5.1
Random-sawn teak	0.008	0.012	4.8
Random-sawn gurjun	0.021	0.029	6.1
Slash-sawn maple	0.024	0.033	6.6

Wood Bending

Investigations into the steam-bending properties of tropical timbers have been continued, and during the year, tests have been completed and reports prepared on about a dozen different species. Timbers tested included ramin, African mahogany, binuang and mbambakovi. Most were found to have properties very inferior to beech or ash with the exception of mbambakori, which appeared to offer some promise as a bending species. Unfortunately, however, this timber showed a pronounced tendency to distort badly both during steaming and subsequently during the setting process.

Further work has been carried out on the method recently evolved of improving the bending properties of tropical timbers by the addition of a supporting layer to the face which will be compressed. It has been found, for example, that by gluing a $\frac{1}{16}$-in. strip of African mahogany to 1-in. thick specimens of scented guarea so that the grain of the thinner piece is at right angles to that of the thicker, the limiting bending radius of the latter can be reduced from about 9 to about 5 in. Further experiments are in progress.

In the field of laminated bending, data on the limiting radii of 12 different species of laminae, mainly of tropical hardwoods, have been obtained. Basic data relating to the influence of factors such as direction of growth rings, moisture content, etc., on the bending properties of laminae have also been obtained.

Seven different species of 3-ply wood have been subjected to the standard bending tests, and the influence of grain direction and other factors on the limiting radii investigated. Woods tested included makoré, nyankom and white afara, but none was found to possess bending properties comparable with plywood of, say, beech or Canadian birch.

Experiments have been started on a larger scale to determine the influence of various factors on the bending and setting to shape of African mahogany plywood. As a result of investigations into the methods of producing small-radius bends for the manufacture of radio cabinets, wardrobes, etc., a new method of producing bends of this type has been devised. The method consists, essentially, of first removing most of that portion of the plywood which normally

would form the concave face of a bend, and replacing it with a low density wood such as balsa, binuang, or western red cedar. The inserted piece is glued into the assembly with the grain parallel to the axis of curvature. Glue is then spread on the exposed face of the insert, and a thin veneer, with its grain at right angles to that of the insert, is placed over it just before the actual bending operation. Before the glue has had time to set, the assembly is placed in position on a heated bending jig and pressed into the required shape by suitably applied forces. Time is then allowed for the glue to set before the completed bend is removed from the jig. Tests have been limited to the production of bends up to 6 in. in width (Plate 3), but work on a larger scale is in hand.

The film on solid and laminated wood bending has been completed and has been used at the Laboratory for instructional purposes.

Co-operation with Industry

Close co-operation with the trade was maintained throughout the year, and 84 visits were made to firms interested in seasoning and bending.

The numbers of enquiries received during the year in connexion with seasoning and bending amounted to 914.

TIMBER MECHANICS

Testing of Timber for Comparison of Species

The testing of timber for the comparison of species has continued on a considerable scale and strength data on material in both the green and the air-dry condition have been obtained for berlinia, mora, morabukea, makoré pterygota and yellow sterculia. Species tested in the green condition include khaya, kokrodua, kurokai, Parana pine, ramin and red sterculia. Matched material of these timbers is now seasoning for tests in the standard air-dry condition.

Supplementary tests have been carried out on further consignments of agba covering a much wider range of material than that tested previously. Particular attention is being paid to the incidence of " brittleheart ", which is common in this species and in many other tropical hardwoods, and its effect on strength properties is being investigated.

Tests on small, clear speciments of Yugoslavian whitewood, home-grown Japanese larch, and native-grown Corsican pine, have been made in conjunction with the tests on structural sizes of these species, referred to below.

Test Methods

Most of the standard testing has been carried out in accordance with a scheme adopted for a test specimen of 2-cm square section. As reported last year two schemes of testing have been accepted internationally for the standard testing of small, clear specimens, one based on a specimen of 2-in. square section and the other on the smaller 2-cm. size test piece. The use of the smaller sample has obvious advantages, particularly with respect to the systematic sampling of small trees and to the preparation of matched groups for all comparative testing. Results of tests made on matched specimens of both sizes from a number of species have shown that there is reasonably good correlation for direct comparison of most strength properties.

The acceptance of the 2-cm. size test piece has involved modifications and

additions to the Laboratory's existing testing equipment. The most important of these was the design of a prototype impact testing machine for use with the smaller specimen. The machine based on the Hatt-Turner principle has proved satisfactory for standard tests and the results obtained are comparable with those from tests using the 2-in test specimen and the standard Hatt-Turner impact machine.

It has been the practice in the past when testing the 2-in. size specimen on the Hatt-Turner machine to use a 100 lb. weight or tup instead of the standard one of 50 lb. for species with a very high resistance to impact loading. For these tests the increments of height are unchanged but the maximum height obtained is doubled in order to give a comparison with values obtained from tests using the standard 50 lb. tup. A study of the performance of both the standard and the modified Hatt-Turner machines has shown that this practice leads to some error. It assumes that the maximum resistance to shock is mainly related to the energy of the final blow and disregards the fact that the number of increments of energy delivered in one method is about twice that in the other. The more logical approach to procedure for this test would be to halve the increments of drop in the case of the larger 100 lb. tup so that not only would the final amount of energy be the same with both weights but the number of units of energy applied and their respective magnitudes would be comparable.

Other studies on impact testing have included an investigation to determine the relationship between three types of testing machine, namely the Modified Hatt-Turner, the Toughness (or Denison) and the Amsler. All three machines are used for impact tests on the small 2-cm. size test piece. A statistical analysis of tests on three species, ash, Douglas fir and spruce, has now been completed and regression equations have been obtained for the results, using any two of the three machines.

Standardization of Tests

Discussions concerning the international standardization of tests have been continued. A second conference on Mechanical Wood Technology was held under the auspices of the Food and Agriculture Organization of the United Nations at Igls, Austria, in August and was attended by an officer of the Timber Mechanics Section.

The Conference was mainly concerned with a study of reports presented by the special study groups which had been appointed at the First Conference on Mechanical Wood Technology held in Geneva in 1949. Proposed methods of tests for fibreboards and for plywood and related materials, as well as reports on the progress made with special assignments covering the principles of structural grading of timber and of nomenclature, were reviewed in detail.

The Laboratory's main assignment was the preparation of a scheme for methods of test for plywood and related material and a paper on the subject was presented for general discussion at the Conference. Although it was not possible in the time available to arrive at a complete scheme of testing applicable to all aspects of the problem, agreement was reached upon the scope of a specification and upon procedures for methods of test for some of the properties of plywood. Test methods for a number of other important properties remain for consideration and the work of the study group concerned is being continued with a view to the completion of a full specification for consideration at the next International Conference.

The Structural Use of Timber

The new structures testing laboratory was completed and handed over to the Section during the year and tests have already been made on industrial type roof trusses of different spans. A system of loading of a novel type has been developed for the testing of trusses and other similar structural units. Its main advantages are its simplicity and ease of operation, as well as its adaptability to a wide range of spans. Loads at each purlin point in a truss are applied by means of a continuous wire rope and a system of pulleys. The rope is continuous on both sides of the truss and is subjected to tension by means of a winch at each end. The reactions at the ends are measured by means of pressure gauges connected to hydraulic capsules mounted under each end of the truss.

This system of loading was first used for the testing of two large industrial type trusses of 50 ft. 6 in. and 59 ft. 6 in. span, respectively, designed by the Timber Development Association and erected by their contractors. The timber used in the trusses, reputed to be imported softwood to 800 lb. grade, was a mixture of Douglas fir, western hemlock and Baltic redwood, but some of the members in both trusses had knots and defects greater than those permissible in this strength grade of timber. The 50 ft. 6 in. truss failed under test at a load of 8·9 tons, owing to a sudden fracture of a severely cross-grained tension member. The 59 ft. 6 in. truss sustained a load of 9·9 tons before it failed with a brash fracture in one member of the bottom tie. A general view of this truss is shown in Plate 4.

Tests have also been made on two small trusses of 19 ft. 9 in. span, one constructed with high-grade, straight-grained, clear Douglas fir and the other with clear Scots pine of similar high-grade quality. Minimum cross-sections were used for the members of each truss. Both trusses proved to be abnormally strong, the Douglas fir sustained a load of 9.9 tons without a definite failure in any member while the load on the redwood truss was 6.4 tons before buckling brought about failure in the rafter twin-members. These tests emphasise the effect of the quality of the timber on the strength of the structure and the desirability of using carefully graded timber.

A consignment of Yugoslavian whitewood, comprising the species spruce and silver fir and a consignment of Corsican pine imported from Corsica have been tested to provide data on the suitability of these timbers for structural purposes. A consignment of home-grown Japanese larch, received from the Forestry Commission, has been graded for strength and tested in structural sizes as part of an exploratory scheme for assessing the value of this species for structural uses.

The Strength of Shear Connectors

Strength tests have been carried out on 2-in. and 3-in. " Bat " shear connectors. The " Bat " toothed-plate connector differs from the " Bulldog " connector in that it is square instead of circular and has sixteen teeth on each face instead of twelve. The tests on these connectors were designed to determine the strength of joints both in compression and in tension parallel to the grain and to compare their strengths with those of ordinary bolted joints for each type of test. As in the previous tests on the " Bulldog " type of connector, the strength of the tension parallel to grain joint was studied with special reference to the end distance of the members used. Tests were also made to study the effect of orientation of the square type connector on the strength of the joint.

An important factor governing the strength of a connector joint is the depth of penetration of the teeth in the individual joint members. A series of tests, using both " Bulldog " and " Bat " connectors, has been made to examine the effect of this variable on the strength of the joint. Other supplementary tests completed include tests to determine the strength of toothed-plate connector joints when used in medium hardwoods and the strength of connector joints in single shear, that is with a single connector.

The Testing of Plywood and Related Materials

A new project for the testing of plywood and allied materials, essentially the scheme of testing presented to the International Conference on Mechanical Wood Technology as mentioned earlier in the report, has been started. Its main object is to provide fundamental data on the strength properties of plywood and to enable comparison of the various types and species of plywood to be made, as well as to assess the effects of various treatments and conditions of exposure.

Modifications have been made of testing machines, and special jigs for panel shear and impact tests have been designed for the work in connexion with this project. A programme of testing has been begun and data have been obtained on the strength properties of $\frac{3}{16}$-in. 3-ply material from thirteen different species of timber.

Performance Tests of Doors

Investigations into the possibility of mechanical performance tests for doors have been made and the results have been communicated to the Committee of the British Standards Institution on whose behalf the investigation was undertaken. From analysis of the treatment to which doors are likely to be subjected in use, the primary strength properties it was considered necessary to investigate were resistance to slamming, resistance to puncture of the panels or facings by kicking or other rough usage and resistance to torsion loading such as occurs when efforts are made to open or close a door against an obstruction at a different height from that of the force being applied. Standardized torsion and slamming tests have been developed and representative types of doors have been tested.

For the torsion test the door is hung on butt hinges in the normal manner with an abutment incorporating a load-measuring device in contact with the bottom of the closing stile and with provision for applying a force to the opposite face of the closing stile just above mid-height. In the initial tests the force was increased progressively until the door failed; later when flush doors proved considerably stronger than panelled types the test was discontinued on reaching a maximum force of 500 lb. Preliminary tests had indicated that the maximum pressure exerted by a shoulder against the door was about 150 lb., but this could be maintained for a short period only and was therefore less severe than a similar load applied continuously as under the conditions of test. Of the thirty-nine panelled doors tested thirty-one were of the lighter type intended for interior use and their average breaking load was about 240 lb. The remainder, slightly heavier doors for exterior use, were on the average about half as strong again. Four doors with mortice and tenon joints failed by splitting of the stiles through the corners of the mortices at loads which showed no advantage in strength over the remaining panelled types of dowelled construction, which failed, typically, by splitting at the ends of the stiles and, exceptionally, when the timber was excessivly cross-grained, by fracture of the stile at the lock recess.

The strength of the flush doors was generally in excess of 500 lb. but those with cores of western red cedar, which is a weaker timber than the other softwood used, split at the hinge fixing at loads mostly below this figure. The stiffness of the doors in this test was generally proportional to their strength.

For the slamming test the door was hung on butt hinges disposed horizontally and was allowed to swing from the vertical position so that the closing edge struck a cill when the plane of the door was horizontal. The apparatus was designed for this operation to be repeated automatically at the rate of about three slams every minute. After preliminary investigation, it was decided to limit the test of each door to 1,000 slams. The endurance of the lighter panelled doors ranged from 232 to 6,858 slams but two similar but heavier doors failed after 52 and 200 slams. The failures were mainly by fracture of the dowels in the closing stile joints. The endurance of the flush door was generally lower and more uneven, ranging from 8 slams to 11,269 unbroken. The failures were principally by splitting of the stiles at the hinge fixing. The reason for the occurrence of this type of failure in the flush doors and not in the panelled doors, and also for the generally inferior performance of the former, is probably their much higher stiffness as registered in the torsion tests, the effects of which, in an impact test of this nature, is to increase the shock effect generally and particularly as transmitted to the suspension.

Abrasion

Standard tests have been carried out on Siamese kwao, panga panga, mora and ramin to examine their suitability for industrial and other types of flooring. Tests of two types of flooring tile and a cork tile have also been made at the request of manufacturers. With the latter a comparison with the standard type wood block in oak was desired.

Many hardwoods relatively new to the flooring trade are being introduced as possible substitutes for maple for industrial type floors and to disseminate information on these, short notes on their relative wearing qualities have been published. The species dealt with during the year include Siamese kwao, muhimbi, krabak, muhuhu, musine, panga panga, afzelia, wallaba and kokrodua.

Miscellaneous

A number of *ad hoc* investigations has been carried out at the request of manufacturers and various government and other institutions. These include tests of scaffold boards of various designs to assess their relative merits; of American ash for general information and comparison with home-grown ash; of comb-joints to assess the effect of various exposure treatments on the different glues used in joint manufacture; and of laminated bends with reference to the influence of method of preparation on strength. A series of tests on several species of home-grown softwood pit-props has been made at the request of the Forestry Commission.

An analysis has also been made of a large series of tests on straight laminated specimens prepared by different methods. A report on the effect of moisture content on the tensile strength of Sitka spruce has been prepared for publication following a detailed analysis of over 1,600 tests.

British Standards Institution

The Laboratory has continued to give assistance to a number of British Standards Institution and Codes of Practice committees. Subjects dealt with

include transmission poles, ladders, grading of timber and softwood for aircraft production.

Advisory Work

The volume of advisory work during the year has shown a considerable increase over past years. A wide range of enquiries, totalling 202 and concerning miscellaneous aspects of strength, have been dealt with, and advisory service has been rendered to government departments and to the Timber Development Association in connexion with the structural use of timber.

Enquiries in connexion with the utilization of timbers for flooring have totalled 104. These have concerned the wearing qualities of hardwoods and softwoods, floor renovations, and treatments and finishings.

At the request of the Department of Health for Scotland housing designs have been examined and advice given on the timber structural components.

COMPOSITE WOOD

Properties of Adhesives

Several of the long-term natural durability trials on plywood adhesives and assembly glues have now passed their fifth year, and time has been spent in analysing data, preparing reports, and reviewing the general course of the experiments. No single series of tests will give a complete account of a glue's performance and there still remains the task of correlating the results of the several current experiments to this end. In the meantime, the following extracts from the records will indicate the probable outcome of the analysis for the main types of synthetic resin glue in current use in Great Britain.

Lap joints of the kind prescribed for testing close-contact and gap-filling glues have been stored under constant conditions of 25°C. and 60 per cent relative humidity, batches being tested at intervals for strength. Summarizing for the urea glues generally over five to six years, and emphasizing that the comment applies only to those actually tested, it can be said that *as a type* their longevity *in terms of high joint strength* is open to question, particularly in thin glue lines. Summarizing for the phenolic and resorcinol glues generally over three to six years, and again emphasizing that the comment applies only to those actually tested, it can be said that *as a type* their performance is satisfactory in both thick and thin glue lines.

Adhesives for plywood manufacture have been tested by storing panels in a normal indoor room and by exposure to the weather on racks in an open field. The results are shown diagrammatically in Figures 1 and 2. Neither urea nor phenolic glues are affected by indoor storage, but under weathering, the former fail completely in less than two years. It appears from the joint-strength figures that the phenolics also weaken, but the apparent fall is brought about by deterioration of the wood, as other forms of test show that the resin itself has undergone negligible change.

The ply-clad frames (illustrated in the Annual Report for 1939-47) have also completed five years' exposure to weather. In this test-unit, the adhesive is used for assembly purposes (i.e. gluing the plywood to the frames), and whilst the rate of deterioration is different from that with the plywood samples of the last paragraph, the results are similar, namely that the phenolic and resorcinol resins are proving markedly superior to the urea types.

Although the urea-formaldehyde glues are less durable than the phenolic

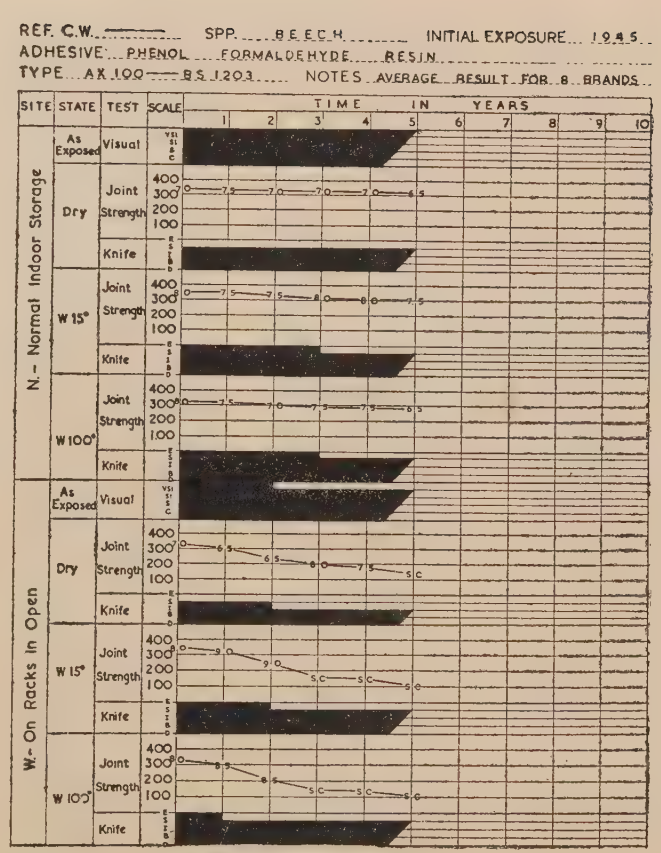

REF. C.W. ——— SPP. BEECH INITIAL EXPOSURE 1945
ADHESIVE PHENOL FORMALDEHYDE RESIN
TYPE A X 100 — B S 1203 NOTES AVERAGE RESULT FOR 8 BRANDS
SITE STATE TEST SCALE
TIME IN YEARS
1 2 3 4 5 6 7 8 9 10
N. - Normal Indoor Storage
W. - On Racks in Open
As Exposed
Dry
W 15°
W 100°
Visual
Joint Strength
Knife
400 300 200 100
V S I S S C
E S B D

FIG. 1

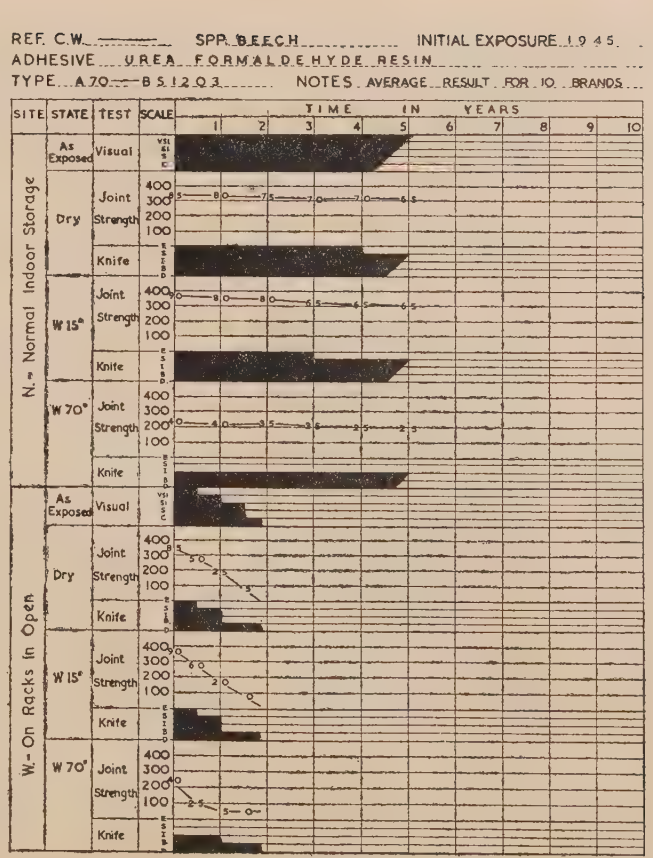

REF. C.W. ——— SPP. BEECH INITIAL EXPOSURE 1945
ADHESIVE UREA FORMALDEHYDE RESIN
TYPE A 70 — B S 1203 NOTES AVERAGE RESULT FOR 10 BRANDS
SITE STATE TEST SCALE
TIME IN YEARS
1 2 3 4 5 6 7 8 9 10
N. - Normal Indoor Storage
W. - On Racks in Open
As Exposed
Dry
W 15°
W 70°
Visual
Joint Strength
Knife
400 300 200 100
V S I S S C
E S B D

FIG. 2

group, they may, however be completely suitable where the exposure of the article to weather is of shorter duration.

Since the tests were begun five years ago steady and continuous—if unspectacular—improvements have been made in the adhesives. In collaboration with the Adhesive Makers' Panel, the Laboratory is reviewing its whole series of long-term tests to see if the changes in formulations justify the inclusion of newer forms of the adhesives. New types of glue (as distinct from minor improvements in existing types) have, of course, been added as they became available.

Routine work upon the more recent glue durability experiments continues. The experiment in collaboration with the Royal Navy on gluing in light naval craft has completed the first two of its ten years, so has the exposure of plywood at the Tropical Testing Station, Port Harcourt, Nigeria. Further collaboration with this station upon assembly glues both for furniture manufacture and for more arduous uses has been arranged. In order to relieve the Station of the labour of extensive mechanical testing of joints, a self-destructive sample has been devised, in which the loading is applied to the glue-line by stresses set up between wooden pieces of different grain direction through changes of moisture content. This " ash-tray " test-piece, as it is called, is illustrated by Plate 5, which also shows how manual pressure is employed to test for failure of the joint. Incidentally, this experiment will provide a direct comparison between the behaviour of material in the tropics and the Laboratory's new Tropical House, of which an account is given below.

At the request of Adhesive Makers' Panel, special tests on the effect of viscosity and pH of animal glue on joint strength have been made. Work has begun on the gluing of preservative-treated timber, a complex subject that is assuming considerable importance in the defence programme.

The Laboratory has undertaken the examination of several wings from Mosquito aeroplanes on behalf of the Royal Aircraft Establishment of the Ministry of Supply. These wings have a known history, and the tests are to discover whether the combined effects of flight and tropical storage have resulted in any deterioration of the wood or of the glue used in their construction.

Work on the revision of British Standards 1203 (Synthetic Resin Adhesives for Plywood) has continued in collaboration with the Adhesive Makers' Panel. It has been suggested that in place of the present arbitrary grouping of glues according to the temperature used in the " wet " tests, one based upon the Durability Classification prepared by the Commonwealth Composite Wood Corresponding Committee should be used. New testing methods which facilitate interpretation of the results have been evolved, and draft proposals are now being considered by the Panel. If accepted, they will be submitted to British Standards Institution for adoption.

Properties of Plywood

To test the weathering of the timber component of plywood, panels are exposed on racks in an open field for a standard period of two years, and after a further conditioning to 12 per cent moisture content are examined for surface checking. The efficacy of surface films in reducing this checking is being examined by similar methods. Most of the films are resin-treated papers, but an impregnated plywood of proprietary make is also under test.

Trials of Timber for Plywood Manufacture

Eleven species have been tried for the manufacture of plywood, two by the full-scale methods (including yield measurements) devised in collaboration with the Plywood Research Panel, and nine by preliminary tests.

These plywood trials give quantitative data for the various operations, and by a study of the Laboratory's Manual—under the rules of which the tests are conducted—a manufacturer can convert figures as presented in the report to the basis of assessment employed in his own factory. Such data, however, indicate only in part whether a timber is likely to be technically and economically useful for plywood. Much thought has been given by the Plywood Research Panel to the interpretation of these data, and the present feeling is that species should be classified into four groups, the highest of which would contain those considered to be fully suitable for plywood manufacture; the second, timbers that are promising technically but for which greater experience is needed; thirdly, those thought likely to be only of use in the country of origin; and finally, species unsuitable for conversion to plywood. The work continues.

Special Heating Methods for Glue Setting

The heating of cauls by low-voltage currents was described in the Report for 1950. The method has attracted considerable industrial attention, and the Laboratory has made several minor investigations to meet particular enquiries. One development has been that of simplified flexible cables.

In radio-frequency work, an investigation has been completed of stray-field heating for setting glued joints, i.e. heating with non-uniform fields applied by narrow electrodes arranged either in simple pairs or in large arrays. This is the form of radio frequency heating most widely used for assembly work in furniture and radio cabinet manufacture, and its effect is to cause the setting of small areas of glue which increase in extent with increase in time or intensity of the treatment. The numerous possible electrode arrangements have been shown to be divisible into six broad groups, and for each in turn, the progressive increases in area of set glueline were followed by making series of joints at successively higher voltages. This has enabled the relative advantages and efficiencies of the different groups to be assessed in a way capable of practical application.

No new experiments have been undertaken in the glueline method of heating, but the testing of laminated beech block samples continues for the purpose of ascertaining whether the rapid glue setting has induced any premature ageing effects.

In both glueline and stray field methods of heating, the rate of setting depends in part upon the electrical properties of the glue. These are usually measured in bulk by precision methods designed for electrical insulating materials, but which are inconvenient for glues which change their properties rapidly at elevated temperatures. A calorimetric method has been developed at the Laboratory which enables the radio frequency conductivity to be measured quickly over a wide range of temperatures, the accuracy being sufficient for the immediate purpose. The results show that conductivity in bulk is not a sufficient indication of the suitability of the glue for radio frequency work, since those setting at the lowest voltage in a joint do not always have the highest conductivity.

Study of Plant and Machinery

Clipping. No major additions have been made to the plywood plant this year, but several minor improvements have been effected. The clipper has been

given a quicker and lighter action as a preliminary to fitting a pre-selector mechanism, and double cutter-heads have replaced the saw-and-cutter on the edger. There has been increased trade interest in the plant, and several special tests have been carried out for firms who, with these facilities, can obtain information without interruption of the normal flow of their production.

Veneer Drying. In the drying of veneer, a very thorough investigation of moisture content variations has been made, to find the correlation between the average figure for a batch and the maximum moisture content over a small area. This maximum is important in plywood manufacture, for if it passes a certain level, blisters may form during the pressing operation—and even a small blister can completely spoil a board. The test-unit in the experiments was a veneer 5 ft. long by 30 in. wide, six of which were distributed throughout a batch being put through the dryer. After drying, five six-inch squares were cut from each sheet along a diagonal, and their moisture content was determined. Each test, therefore, gave a mean based on thirty figures and also first, second, etc., maxima. From the study of large numbers of such test results, the data of Table 2 were obtained. The general averages (or ' means of thirty ') are grouped in the left column, and against them are shown the proportion of the thirty that can be expected to lie below the moisture content given at the head of the table. Thus with a mean between 3 and 5 per cent, 95 per cent of the veneer will normally have a moisture content below 20 per cent.

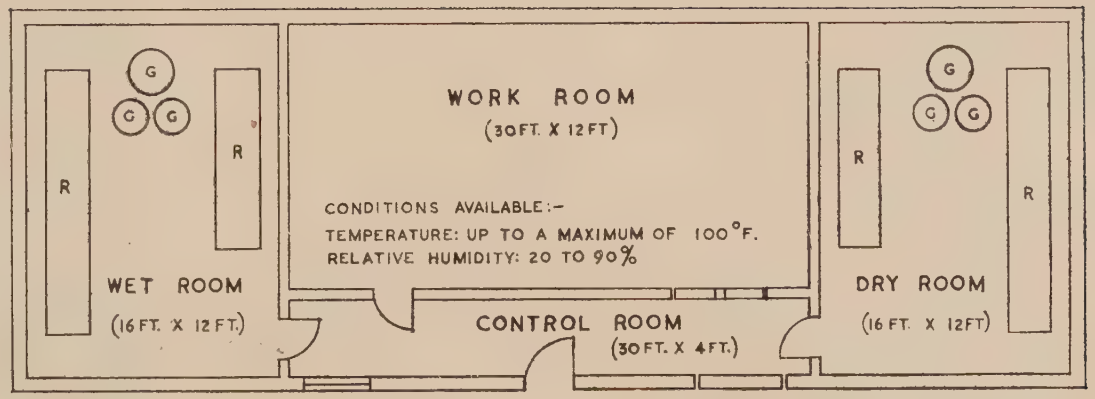
TABLE 2

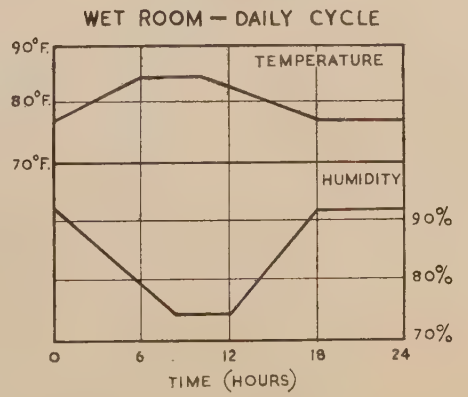
Variation of Moisture Content in the Drying of Veneer.

General average moisture content (%)	Maximum allowable moisture content (%)		
	20	15	10
3, 4, and 5	95	87	55
6, 7, and 8	77	58	5
9, 10, and 11	65	17	3

For significant results, studies in the variation of moisture content require a very large number of figures, and in the last Annual Report, mention was made of a continuous-operation oven which enables moisture content determinations to be made at the rate of forty per hour. In an attempt to increase the output, radio-frequency heating was tried for drying out the smaller veneer squares, and *as such* it did well. For mechanical reasons, however, the veneer must be held between platens, and these must be kept hot to prevent surface cooling of the radio frequency heated veneer. It was found easier to use the heated plates themselves, and a dryer of this type is now under construction, the 8-in. square platens being heated by low-voltage current to a temperature of about 200°C. In preliminary tests, 0.064 in. thick veneer has been dried in fifteen seconds.

Glue Mixing. For mixing synthetic resin glues in batches of between 50 and 100 pounds, a hand-operated basket whisk has been found a most efficient tool.





G = GLUE STORAGE
R = STORAGE RACKS

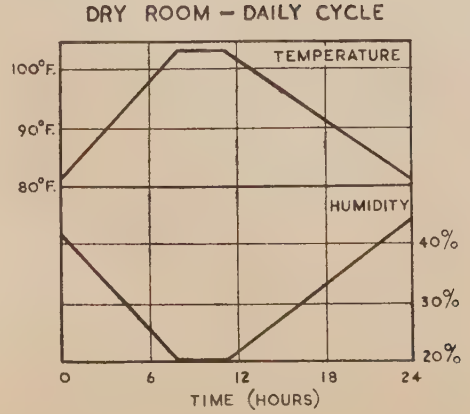


FIG. 3. F.P.R.L. TROPICAL HOUSE

In addition to its use by a simple circular motion round the side of the vessel, it is more advantageously employed with a combined twisting and up-and-down movement. This action has been reproduced by mechanical means in the mixer shown by Plates 6 and 7. The whisk is driven by an air motor at the rate of about 75 r.p.m., the spindle running into the glue vessel at roughly 30° to the vertical. The vessel itself is mounted on a turntable equipped with a simple band brake, the purpose of which is to make the vessel's rate of rotation less than if freely driven by the whisk, and so to increase the latter's shearing and mixing action. It is usual to sprinkle the powder component of the resin glue on to the top of the mix at a steady rate, but the actual rate does not seem critical; indeed, the whole quantity required by a batch has been added at once without ill effects, although the operation took considerably longer. The mixer is now being tested with many types and brands of glue.

Tropical Testing

New equipment has been added to the Section by the conversion of the old " Dry Rot House " into a tropical house in which the daily cycles of temperature and humidity of the Wet and the Dry Tropics can be reproduced.

A plan of the building is shown in Figure 3 with details of the conditions in the rooms. The temperature and humidity cycles for the Dry Room are based on records for the dry months at Jubbulpore and Khartoum and those for the Wet Room on figures for the wet months at Rangoon, Lagos, Jubbulpore, Singapore and Calcutta.

In addition to the Wet and Dry Rooms there is a workroom in which any constant air temperature and humidity can be maintained and solar heating effects can be obtained by infra-red lamps. The large floor area of this room can accommodate plant and large structures, such as aircraft wings, for the study of gluing techniques under tropical conditions.

A complicated plant is required to maintain the specified cycles of temperature and humidity which call for the circulating air to be heated, cooled, dried and wetted each day. Control is achieved by a balanced-pressure, compressed-air system which is regulated by a revolving cam the profile of which traces out the specified conditions of temperature and humidity.

In addition to the room required for the Laboratory's own experimental work there is enough space in the building to accommodate a limited number of storage tests for industry, and some are already in progress. Plate 8 shows the dry tropical room.

Testing of Adhesives

In the testing of adhesives, joints are immersed in water at three standard temperatures, viz. 15°C. ± 5°C., 70°C. ± 2°C. and 100°C. A battery of tanks has been constructed to produce these conditions, thermostatic control being fitted where necessary, and methods of handling large numbers of test pieces in and out of the hot water have been developed.

Advisory Work In Composite Wood

There has been a large increase in advisory work during 1951, 511 enquiries having been received compared with 385 in the previous year.

An interesting example of successful co-operation in the advisory work is the development of laminated shoe beams. A shoe beam is the member in an

electric train which carries the metal contact-shoe through which power is obtained from the conductor rails. In 1946 the Laboratory learnt that the London Transport Executive were considering the replacement of their wooden shoe beams by a design in steel, and suggested to the Executive that a laminated wood construction might instead replace the solid wood no longer obtainable at the time. The executive accepted the suggestion, and sample beams bonded with various adhesives were made by the Laboratory for service trials on the London Underground. In 1951 the Executive were satisfied that the form of construction is an improvement on the solid hardwood beam which they had used in the past, and were obtaining several hundred laminated beams to be put into ordinary service. In this instance not only was a saving in steel effected, but also the substitute proved better than the material it replaced.

WOODWORKING

Sawing and Machining Research

Chip Formation. The behaviour of wood in cutting is far more variable than that of metal owing to the effect of the cellular structure of wood. In metal cutting, the chip is produced by a shearing process originating at a plane extending from the tool edge to the surface of the material being cut. A very thin layer of metal at this shear plane undergoes plastic deformation and, as the tool advances, forms the chip which slides up the tool face. Though the metal is subjected to a high crushing stress, its volume remains essentially unchanged and if lateral deformation be ignored, the ratio of depth of cut to chip thickness can be taken as equal to the ratio of the chip length after and before removal. Wood, being composed of hollow fibres and other types of cell, has innumerable cavities which tend to close up when the material is under compression and the volume decreases appreciably. The direction of cutting relative to the grain of the wood, the moisture content, the presence of zones of weakness or local variations in density affect the reaction of the wood. In addition, the degree of sharpness of the cutting edge, the cutting angle and the rate of cutting have considerable effect on the results. Although in all these matters the field of study is wide, preliminary work has already provided much useful information. A suitable technique has been developed for observing, at magnifications up to 240, chip formation at slow rates of rectilinear cutting for all directions of the grain, cutting angle from 0° to 40° and accurately controlled depths of cut. In the apparatus used for this purpose is incorporated a sensitive dynamometer for measuring the cutting and thrust forces imposed by the tool on the wood. Series of tests have been carried out on various hardwoods over a range of cutting conditions with the object of determining the relation of these forces to the depth of cut. Our previous studies had suggested that the relationship between these factors might be linear, whereas recent results have shown it to be of less simple form. The investigations will be continued in both rectilinear and curvilinear cutting over the full range of speed, because exact information on this subject is required in analysing the somewhat paradoxical results obtained in sawing, planing and other operations concerning the influence of feed speed and number of cutting points on the power.

Sawing Studies. Theoretical studies in sawing have been continued and one useful result of the work has been the derivation of formulae to determine the maximum permissible feed speed, or pitch for a given feed speed, for correct cutting action with spring-set teeth. These formulae are based on the critical

condition of cutting when each tooth is engaged with the wood to the full width of its cutting edge and its inner corner is in cut. This side of a spring-set tooth is inclined outwards by the setting operation and thus it rubs on the wood over an area depending on the tooth penetration. Such rubbing will interfere with the efficiency of the cutting action and may cause overheating of the tooth tip. The teeth of wide bandsaws are seldom spring-set, but if so treated, their tops are usually ground square by the automatic saw sharpener, whereas spring-set teeth on circular and other types of saw are given alternate top bevel. No formula is required for square-topped spring-set bandsaw teeth because interference occurs at any feed speed. It is of interest to note, however, that this particular action has been found useful in cutting certain species of gummy timber. The extra depth of penetration of the outer edge of the teeth, equivalent to the use of double pitch, is an advantage in dealing with the gumminess of the material. The side pressure on the inner tips, though producing some heat, holds the teeth steady in the cut and helps to overcome the tendency of the hard wood to deflect the spring-set teeth. When alternate top bevel is given to the teeth, engagement of the inner tips does not occur until a critical value of the tooth penetration has been reached. Interference will be brought about by using too long a pitch for given cutting and feeding speeds, or too fast a feed with a given pitch. Spring-setting appears to be preferred in parts of India, where comparatively narrow band saws are often used for conversion purposes, and it is customary to give top bevel to the teeth.

Sawing investigations have included series of tests on agba over a wide range of feed speeds to determine the relationship of feed to power for long, medium and short tooth pitches. Particular attention was directed in these tests to the effect of tooth interference on power, tooth heating and blunting and the influence of the particle size of sawdust on gum-depositing. Various novel forms of tooth have been tried on circular saws for specific purposes such as reduced power, smoother cutting or resistance to blunting. One promising method of improving edge-life was first tried in a sawing investigation on ' Rhodesian teak ' in 1949. It consisted merely of strengthening the tooth point by forming a bevel or a radius at the arris of the tooth top and the outer side. Smoother sawing was obtained, especially with the rounded point, and in both instances slightly reduced power and an apparent increase in the life of the cutting edge resulted, but no further action was taken after the idea had been tested on what is an extremely refractory timber. The wood had practically a grinding action on the teeth and it was decided after this very severe test that little advantage appeared to be derived from such strengthening of the corner. During the year, however, a visitor from Western Australia mentioned that saws with teeth bevelled in this manner were used in his mill for dealing with unusually hard native timbers which would otherwise have been almost impossible to saw. Further tests in this connexion have therefore been put in hand.

Woodworking Tests

Major scale woodworking tests were carried out and reports prepared on the following African species, all kiln-dried: makoré, mtondo, mjombo, mchenga, utile, danta, nyankom and idigbo.

Woodworking and nailing tests were made on brittleheart and normal wood present in a consignment of agba.

Nailing

An investigation on the nailing properties of timber has started, and a suitable technique developed. Tests were carried out and a report prepared on eight species—ash, beech, celtis, makoré, mchenga, oak, sweet chestnut and utile. The results indicated that the tendency of timbers to split in nailing is proportional to their hardness-cleavage ratio. Further tests were made on beech to determine the influence of nail position on splitting.

Conversion Studies

A conversion study has been made on a consignment of twenty logs of plantation-grown Japanese larch. The trees, many of which were 60 ft. or over in height, had been cross-cut into 20-ft. lengths and both butt and middle logs were converted into commercial joinery sizes. Outturn of sawn stock as compared with true volume under bark showed an average of 56.6 per cent for the butt logs and 51.4 per cent for the second length logs. Conversion of the top logs was not attempted as little useful stock would have been obtainable owing to poor shape and an excessive number of knots.

Wood Boring

Further work has been carried out on the equipment for research in boring. A drill-point tester was designed and constructed for the accurate measurement of the angles and dimensions of the various types of boring bit used in these studies. Improvements have been made to the special boring machine, which now has a range of spindle speeds from 950 to 6,000 r.p.m., and its dynamometer has been modified in the light of experience gained in the preliminary testing.

General

Following the completion in the early summer of the new experimental woodworking laboratory, the work of installing and testing the new machines has been in progress. In addition to the design and construction of components for the work, direct observations on the action of cutting in the operation of moulding have been made. Commercial high speed photoflash equipment was studied to find whether it is suitable for use in sawing and machining research, and various tests, including sawing studies on logs of Trinidad mora, have been carried out on the new 48-in. band racksaw.

Advisory work in Woodworking

Advisory work during the year has been concerned with:— Sawmilling and woodworking problems, design of machine tools, methods of improving tool performance and of overcoming difficulties in cutting timbers of abrasive nature. Design of furnaces and destructors for burning wood waste; production of fuel briquettes. Collection, drying and utilization of sawdust and wood chips. Production of charcoal, kiln design and collection of by-products.

One interesting enquiry brought the problem of devising an improved method of trimming battery separators after treatment. The material was in a moist woolly condition and no suitable form of band or circular saw tooth could be found. The solution proved to be the use of a high speed rotary cutting disc. For other similar enquiries, various designs of special saws have been made up and tested before recommendations have been tendered as to types best suited for specific purposes.

Over 300 technical enquiries were dealt with during the year, and advice was sought by 130 technical visitors.

WOOD PRESERVATION

Testing of Wood Preservatives

During the year three more wood preservatives have been put under test at Princes Risborough and Thetford at concentrations varying from 0.1 to 15 per cent according to the new method of test described in last year's Report. These are the water-borne preservatives Ascu and Boliden salts, and the solvent-type copper naphthenate. Ascu is a copper-chrome-arsenic mixture and Boliden salts a zinc-chrome-arsenic mixture developed in Sweden during the past 15 years. All the important modern water-borne preservative mixtures are now under test by this method.

Natural Durability of Timber

Tests on 16 new timbers have been started at Princes Risborough and Thetford during the year. There are now 230 timbers being tested at each of these sites. The main object of these trials is to measure the relative durability of different species of wood. In addition, the results can be used as a guide to the actual life that would be obtained from these timbers when used in contact with the ground in this country. Strictly speaking, however, the results can only be applied directly to timber of the same cross-section as the test specimens, i.e. 2 × 2 in. as at present there is no information as to how the life of a timber in service varies with size. In the Laboratory small test pieces lose weight more rapidly through decay than larger ones. It is believed that the service life of perishable timbers such as beech or pine sapwood does not vary much with size, but that with durable timbers such as oak or teak the life increases. In order to obtain information on how size and service life are related with timbers of different durabilities additional tests have been started. These consist of measuring the life of matched specimens of different sizes varying from $\frac{1}{2} \times \frac{1}{2}$ in. to 4 × 4 in. in cross-section. So far, two species are being tested, *viz.* lime, which is a typical non-durable species and Baltic redwood, a commonly used timber of moderate durability.

Transmission Poles

As a result of the premature failure of a large number of creosoted electricity transmission poles which has been found to be due to unsatisfactory creosoting, a revision of the appropriate specification for poles has been made following representations from the Electrical Research Association. The new British Standard Specification for poles puts much more stress on preservation and it is hoped that this will help to reduce the number of failures in the future. The new specification is intended to be a comprehensive one for all species and when sufficient data are available on strength and durability, other species in addition to Baltic redwood and larch will be considered for inclusion in it. These include home-grown Douglas fir, western red cedar, western hemlock and Japanese larch; and preliminary pressure-creosoting treatments have been carried out to provide information on suitable methods for preserving some of these timbers and also to obtain material for tests on the effect of treatment on strength.

Some time ago, at the request of a committee of the Electrical Research Association, a detailed examination was made of poles that had been treated

in the line by a process intended to arrest internal decay in poorly creosoted poles. This work has now been completed and a report submitted.

Standard Impregnation Tests

Work has been continued on the determination of the permeability of different timbers. Ten species have been investigated during the year and ramin and pterygota were found to be permeable and easily treated by pressure or by the open tank process. Dahoma, mjombo, makoré, yellow sterculia, nyankom, berlinia, peroba and mchenga were found to be resistant or very resistant to impregnation. This project has provided very valuable information now that so many new timbers are being used and treated and 150 species have now been tested in all. As heartwood and sapwood usually differ greatly in permeability they are tested separately. Most foreign timbers contain only a small amount of sapwood, but there are some which have a considerable proportion. There is no difficulty in advising on the treatment of these timbers so long as the sapwood is readily distinguishable from the heartwood. Some timbers, however, have a permeable sapwood and a relatively impermeable heartwood which cannot be readily distinguished from one another and this makes it very difficult to advise on the best treatment of these timbers. Obeche is a good example of such a timber which is now being widely used.

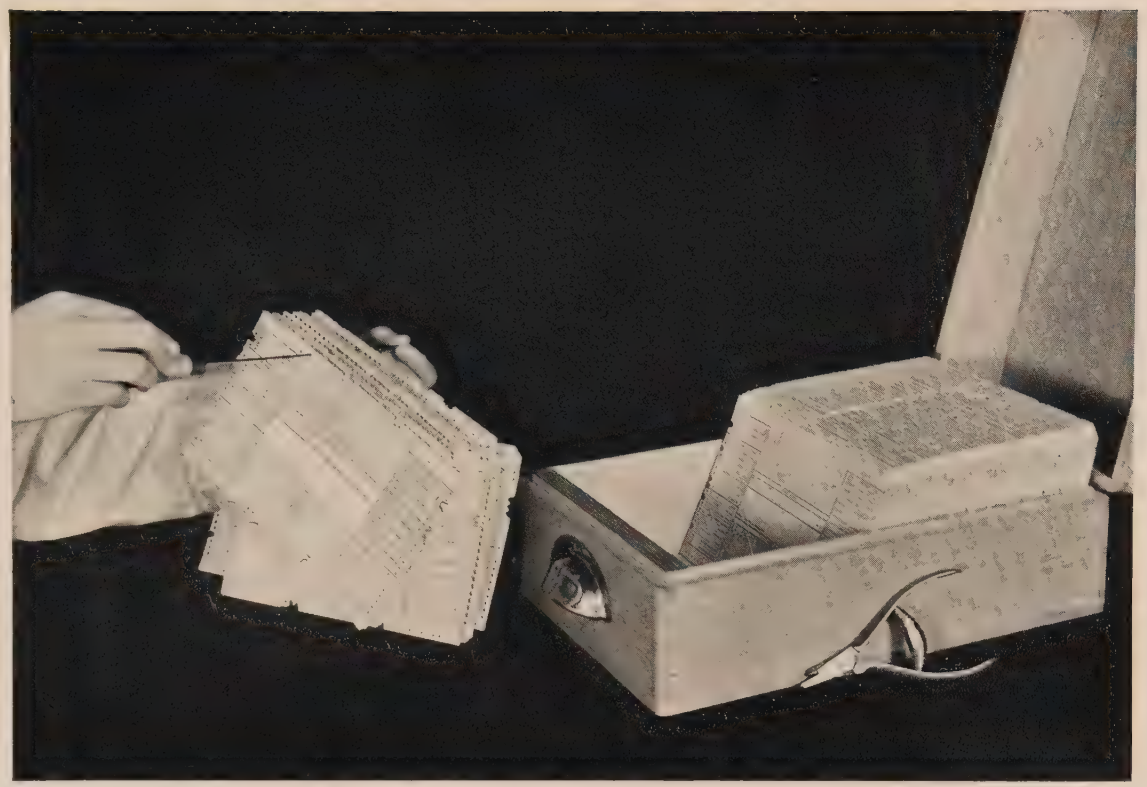
Studies on the Injection of Liquids into Wood

In the course of studies on the effect of temperature and pressure on the penetration of creosote into Douglas fir, it became evident that there is a relationship between the temperatures and pressures that can be used without causing collapse of the wood and an approximate correlation has been determined. For observing the collapse of wood during pressure treatment, a new technique has been developed by which it will be possible to establish a more accurate relationship between the actual temperatures and pressures. The work has proved difficult and has taken much time, but it has been pursued as it is of primary importance for further studies of the penetration of liquids into wood.

Sleeper Investigation

Experimental sleepers have been under observation at twelve different sites during the past 16 years. Some of them are now being removed as the tracks in which they are laid become due for relaying. Those at Marden, on the Southern Region, were removed this year. The results obtained at this site confirm the belief that for creosoting sleepers of, for example, Baltic redwood, which contain a mixture of absorbent sapwood and relatively non-absorbent heartwood, the empty-cell process is superior to the particular full-cell treatment used by the railways, quite apart from a possible saving in creosote.

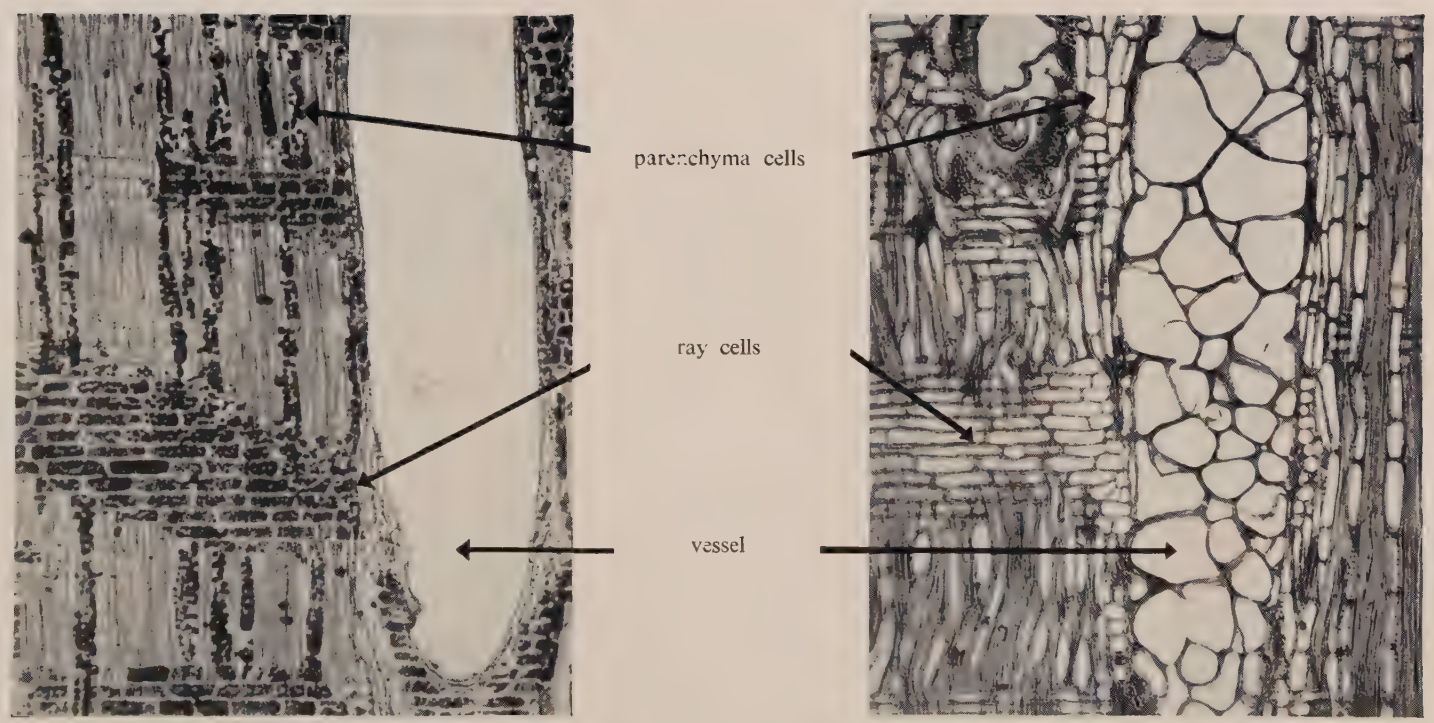
Sleepers of home-grown Scots pine and Douglas fir were included in these trials. At Marden the Scots pine has given a very similar performance to that of the Baltic redwood, which is, of course, the same species. They also have given better results when creosoted by the empty-cell process. After 16 years the Douglas fir were in very good condition and have given better results than any of the other sleepers. This is believed to be owing mainly to the characteristics of the home-grown wood itself, one of which is the presence of large, sound knots which appear to hold the wood together and so reduce the tendency to split which is a noticeable defect of straight-grained Baltic sleepers.



The method of sorting is shown on the left and the clippers for notching the cards on the right.

THE F.P.R.L. LENS KEY TO HARDWOODS

PLATE 1

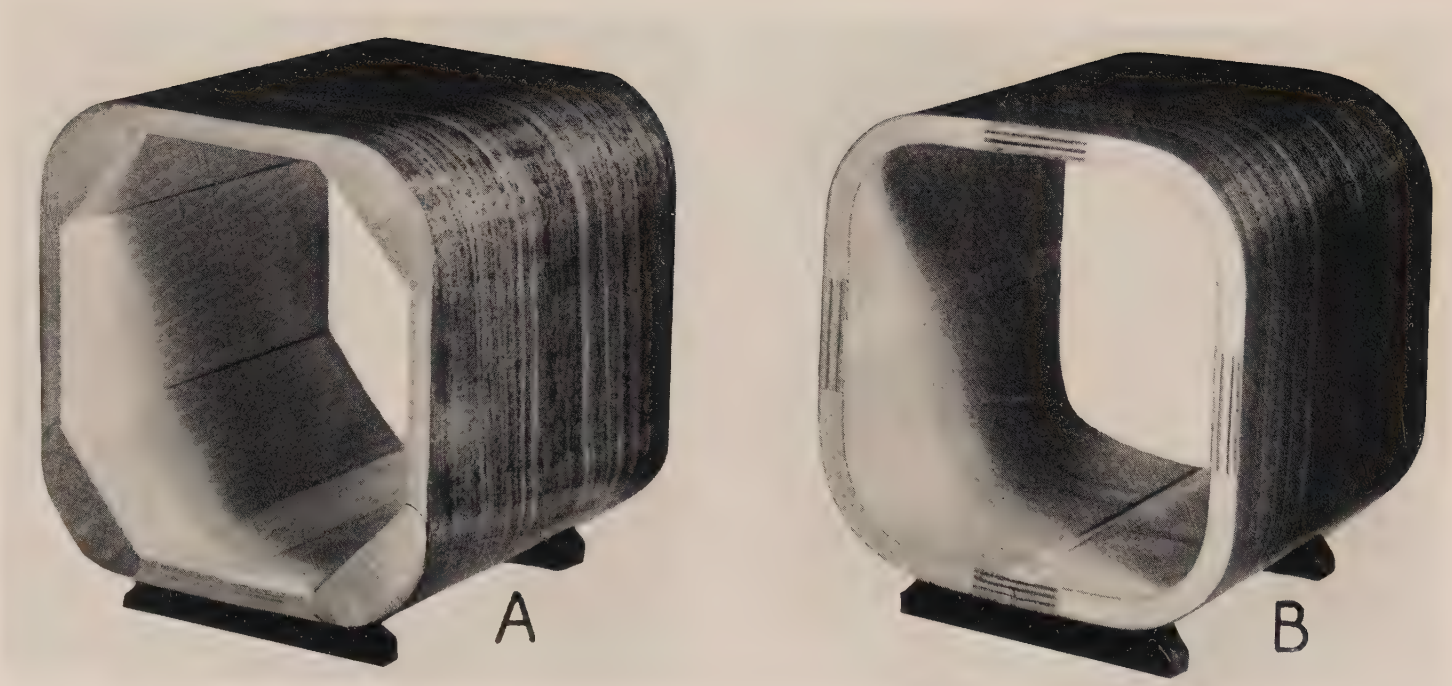


(a) Sapwood showing living ray and parenchyma cells packed with starch grains and an open, sap-conducting vessel (x120)

(b) Heartwood with dead, empty ray and parenchyma cells and a vessel closed by bubble-like tyloses which have grown out from adjacent ray cells (x120)

TRANSFORMATION OF SAPWOOD TO HEARTWOOD IN OAK

PLATE 2



A. Example of orthodox corner-block construction in a radio cabinet
B. Example of the Laboratory's corner, with balsa core

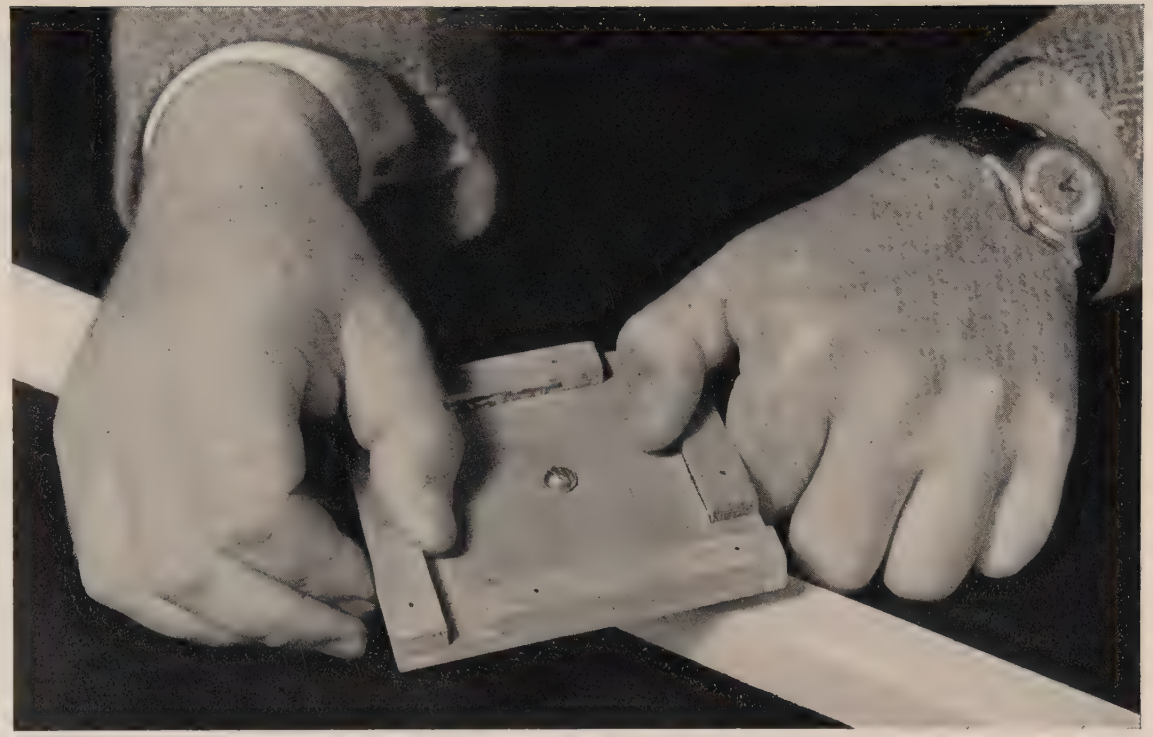
AN IMPROVED METHOD OF MAKING CORNERS OF SMALL RADIUS

PLATE 3

The fracture in the bottom tie can be seen above the letter 'J'.

THE TIMBER DEVELOPMENT ASSOCIATION TRUSS AFTER FAILURE

PLATE 4



The strips are attached to the base by glue alone, the two small holes in each being merely for location pins withdrawn after manufacture. The samples are mounted in racks in the test environment (e.g. as in Plate 8). Stresses set up in the glue line through movement of the timber itself may lead to failure, when the cross-strips can be dislodged by light finger pressure.

THE ASH-TRAY SELF-DESTRUCTIVE SAMPLE

PLATE 5

MECHANICAL MIXER FOR SYNTHETIC RESIN ADHESIVES

PLATE 6

MECHANICAL MIXER FOR SYNTHETIC RESIN ADHESIVES

PLATE 7

Here, test pieces, plywood sheets and assemblies and manufacturers' products undergo storage tests

THE DRY TROPICAL ROOM

PLATE 8

Preservative Treatment of Plywood

The increasing use of plywood under conditions favourable to decay has made it desirable to obtain information on the treatability of various species of plywood. Unfortunately, the data on the permeability of various species as determined by the standard impregnation tests cannot always be applied satisfactorily to these species when used in veneer form as in plywood, and it has been found necessary to develop a test for determining the treatability of plywood made from different species of wood. A number of different plywoods have been treated but there is some difficulty in applying the results of these tests to commercial plywood as this is often made up of more than one species, and while the face veneers are specified the wood used for the core may not be.

Fire Resistance of Timber

The technique developed at the Laboratory and previously used for measuring the inflammability and ignition temperature of wood in its natural state is being adapted for the measurement of the effectiveness of fire-proofing compounds. It is hoped that this method will avoid most of the disadvantages associated with the empirical type of tests normally used. The results of the exploratory work have been satisfactory.

Advisory Work in Wood Preservation

The advisory work continues to take up much time and is on the increase. During the year 450 enquiries were dealt with by letter and about 200 by telephone, and a large number of visitors was received.

MYCOLOGY

Culture Collections

The collection of cultures of wood-inhabiting fungi has been maintained in good condition and a revised catalogue has been prepared and distributed to collaborating laboratories. Many requests for cultures continue to be received both from industrial firms and from other research laboratories.

In view of the discovery of the part played by various species of Ascomycetes, such as *Chaetomium* spp., in causing deterioration of timber, it will be necessary in future to maintain cultures of these fungi in the culture collection.

Further progress has been made in the preparation of standardized descriptions on perforated cards of the cultures of wood-rotting fungi in the collection, and cards for some 75 species have been completed.

Cultures for identification have been received from the East African Agricultural and Forestry Research Organization, the Department of Agriculture, Jamaica, the Rubber Research Institute of Malaya, and the Instituto de Sanidad Vegetal, Argentina, as well as from a number of workers in this country. Identification of such cultures sometimes involves a good deal of work, but the experience gained is useful. Identification of fungi isolated from tropical timbers is often difficult as the Laboratory's collection of wood-rotting fungi does not yet include a sufficiently wide range of species, and efforts are being made to obtain further specimens and cultures of wood-rotting fungi of economic importance in the tropics.

Physiology of Wood-rotting Fungi

Further experiments to determine the longevity of fungi in air-dry wood have been started and the original experiment with fungi resistant to desiccation

continues. The question often arises as to the length of time during which dry rot may remain in a dormant condition in infected timber in a building, and a range of samples infected with *Merulius lacrymans* is being kept at various humidities and the vitality of the fungus after varying intervals of time tested by culturing.

An experiment has been carried out to determine the effect of prolonged soaking of coniferous timber in water on its resistance to decay. Contrary to the findings of a Finnish worker, such soaking appears to have little effect on its resistance to decay.

The study of the metabolic products of wood-inhabiting fungi has been continued in co-operation with Dr. Birkinshaw at the London School of Hygiene and Tropical Medicine. A joint paper has been prepared for publication on the metabolic products of *Polyporus benzoinus;* in this a new compound named ungulinic acid has been described together with notes on its antibiotic properties. A fungus isolated from East African pencil cedar, *Daedalea juniperina*, is now being examined.

Laboratory Tests on the Natural Durability of Timbers

Standard laboratory tests on the resistance to decay of the following timbers have been completed:—alder, berlinia, binuang, chumprak, greenheart, *Khaya* sp., lime, pterygota, rauli, and utile. Tests on sweet chestnut, brown sterculia and Bermuda cedar are in progress. A test on a more comprehensive scale is in progress to compare the decay resistance of the wood of European and of Japanese larch grown in this country.

The toxicity to fungi of further samples of extractives isolated from naturally durable woods by Professor King at Nottingham University has been examined by tests in agar.

Laboratory Tests on Wood Preservatives

Possible improvements in the technique of carrying out laboratory wood block tests on preservatives have been studied further and the moisture conditions which develop in test pieces on cultures in glass bottles fitted with various types of closure have been studied. The indications are that the optimum moisture conditions for the fungi develop in bottles closed with a metal or plastic screw-on lid in which a $\frac{1}{2}$-inch hole has been drilled and then stoppered with cotton wool, which permits gaseous interchange between the air in the bottle and the outside atmosphere.

Comparative tests on two water-soluble preservatives carried out by the standard Kollé flask and by the Leutritz soil contact methods have yielded very similar results. Certain test fungi appear to grow somewhat better in the presence of soil, but others make just as vigorous if not better growth when cultured on malt agar.

Standard wood-block tests have been carried out on several petroleum derivatives, such as methyl naphthalene, and on a number of proprietary products submitted by their manufacturers.

Tests on the resistance to decay of treated fibreboards and chipboard and of plywood impregnated with synthetic resin have also been made. Samples of wood coated with proprietary synthetic resin finishes have been exposed to fungal attack under controlled conditions in the laboratory, but the finishes were not found to be effective in preventing the penetration of the test fungi.

It has been suggested that contact with materials containing free lime greatly reduces the effectiveness of wood preservatives of which the major constituent is sodium fluoride. Tests using blocks that have been impregnated firstly with sodium fluoride and subsequently with soluble calcium salts are in progress to determine how far the toxicity of sodium fluoride is depressed by precipitation in the wood of the fluorine as insoluble calcium fluoride.

The toxicity to fungi of the vapours of furfural and of acetic acid has been examined and a paper describing the method of test used and the results obtained on a number of compounds has been published.[1]

The toxicity to sap-staining fungi of phenyl mercury acetate has been compared with that of ethyl mercury phosphate, using the unseasoned sapwood disc method, which proved both convenient and effective. The phenyl mercury compound proved to be less effective than the ethyl mercury salt for the control of blue stain and moulds.

Tests on Fungal Resistance of Fire Hose

Tests of the rot and mildew resistance of eighteen types of fire hose have been undertaken on behalf of Fire Research Organization. As this investigation was somewhat outside the normal scope of the work done in the laboratory, preliminary tests were carried out using a variety of methods in order to gain experience of fabric testing and to ascertain the most suitable test procedure.

In the principal test used, samples of the hose are exposed to pure cultures of the cellulose-destroying fungus, *Chaetomium globosum*. The pieces of hose under test, after being sprayed with a suspension of the fungus spore, are placed in contact with the agar medium containing all essential growth materials, except carbohydrate, in suitable culture vessels. Together, the carbohydrate (cellulose) of the test fabric and the salts in the agar make a complete growth medium for the fungus and rapid growth of the fungus is encouraged by keeping the culture vessels at a temperature of 86°F. (30° C.). After appropriate periods, further growth of the fungus is checked by drying the test pieces, which are then returned to Fire Research Organization where strength tests are carried out upon them. The rate of attack by the fungus under these conditions is very fast. In preliminary tests ordinary fire hose samples were so weakened after 16 days in the culture vessels that they fell to pieces on removal.

Deterioration of Timber in Water Cooling Towers

The investigation on the breakdown of timbers in cooling towers has continued, and further samples of timber showing surface breakdown have been examined. Species of *Chaetomium* have been isolated from most samples whether softwood or hardwood. Laboratory experiments, using modifications of the method employed in fabric testing (see above), have shown that *Chaetomium globosum* can cause rapid decay and loss of weight in beech wood containing added nutrient inorganic salts. Attack proceeds at a slower rate when no nutrients are added. Chemical analysis of beech wood decayed by this fungus has shown that preferential removal of the cellulose occurs but that the percentage solubility of the wood in dilute alkali does not increase as is the case with a typical brown rot. Comparable decay of beech by two other species of *Chaetomium* has been demonstrated.

[1] Findlay, W. P. K. & Vernon, J. W. A Simple Method for Testing the Toxicity of Volatile Antiseptics to Wood-rotting Fungi. *Ann. appl. Biol.*, 1951, **38** (4), 876-880.

Though attack of softwood by *C. globosum* has been shown in pure culture on a number of occasions, the attack has been slight and no reproducible results have yet been obtained.

The nature of the decay caused by *Chaetomium* is being studied further in comparison with typical brown and white rots caused by Basidiomycetes and the effect of early stages of attack by all three types of decay on the toughness (shock resistance) of the wood examined.

The type of fungal breakdown found in water cooling towers is now known to assume economic importance in other situations. In particular, decay caused by these fungi has been noted in alder and birch plywood stored in damp conditions, in non-durable hardwoods imported from the tropics, and in one instance on the surface of beech floor blocks in a damp room.

A number of cultures of Ascomycetes and *fungi imperfecti* isolated in South Africa from treated hardwood in contact with the ground have been studied. It has been shown that six of the twenty species examined decay beech in a manner similar to that of *C. globosum*. It is possible that under special circumstances almost any fungus capable of attacking cellulose may be able to bring about decomposition of ligno-cellulose in wood.

Dry Rot in Buildings

As evidenced by the large number of advisory enquiries received, dry rot is still extremely prevalent and a number of outbreaks in post-war buildings have been reported. In many of these the primary cause of the trouble could be traced to the use of unseasoned timber which was covered with an impervious material before it had had time to dry out. There is a much greater risk of dry rot developing in unseasoned flooring laid solid on to site concrete than when it is used in a suspended floor in which the boarding has a better chance of drying out *in situ*, if the sub-floor ventilation is satisfactory.

Another common cause of dampness and rot is the use of inadequate damp-proof courses in solid floors—a brushed coat of bituminous emulsion or a layer of thin roofing felt cannot be considered an adequate seal against damp rising up from site concrete, but unfortunately such materials are still used.

Work has continued in co-operation with the Building Research Station on the development of an antiseptic plaster for application to walls deeply infected with the strands of the dry rot fungus and improved methods for testing the effectiveness of such plasters in the laboratory have been devised. An article describing the results so far achieved has been prepared for the technical press and will shortly be published.

Decay of Timber in Boats

The decay of woodwork in small craft has been the subject of many enquiries and it is clear that considerable wastage of timber and labour is incurred in repairing damage caused by decay in wooden boats. It is evident that the annual cost of all this repair work is very high. One writer estimates that over £1½ million is spent annually on the repair of yachts alone and that nearly £1 million in addition is probably spent on fishing and other commercial craft and on open boats. Much of this decay results from faulty design, which leads to the penetration of fresh (rain) water, and to the absence of adequate ventilation. Often less durable timbers are used than formerly, when teak was more readily available, and the employment of such timbers calls for an increased use of wood

preservatives. Correspondence with a number of naval architects and yacht designers has revealed a widespread interest in the problem and a joint discussion of all those interested has been arranged to decide what action should be taken to make more widely known the available information on the subject.

Bridge pontoons, which are usually constructed of a plywood skin fixed to solid timber framing, can suffer serious deterioration if stored in the open so that rain water can accumulate inside them. Discussions have been held with Service authorities regarding the best methods for preservation of these craft.

A paper on Fungal Decay in Woodwork (in boats) has been published.

Decay of wooden vessels is also of considerable economic importance in many tropical countries and reports from East Africa indicate that extensive repair work is often needed in modern craft operating on the great lakes there. Samples of decayed timbers from boats and cultures of fungi isolated from them have been sent to the Laboratory for identification from Dr. Rudd-Jones, who is investigating the problem in Kenya.

Advisory Work in Mycology

Once again the volume of advisory work has shown an increase over the previous year. The number of enquiries dealt with by letter just exceeded 1,000. Many visits to inspect property affected by dry rot have been called for and a number of buildings have been visited on behalf of other departments and local authorities, but the number of inspections of privately-owned buildings has had to be curtailed, on account of shortage of staff. Among advisory enquiries of interest the following may be quoted as examples:—

Inspection and report on a long wooden refuelling jetty built during the war and already showing severe and extensive decay in timber deck and main bearers; prevention of mildew on furniture and woodwork of car bodies shipped overseas; inspection of arrangements for maintaining continuous water spray over large numbers of birch logs held in storage; prevention of mould growth on chip baskets in storage; decay in corks in bottles full of wine, decay in woodwork of grain silos in Malta; use of sawdust as a mulch for fruit trees; decay in beech draining boards; mould growth on cosmetic pads; mould growth and rot in acoustic tiling in swimming baths.

ENTOMOLOGY

General

For the first time for many years it has been possible to devote greater attention to the Section's programme of research. Advisory and instructional work have continued to make heavy demands on the time of the staff but correspondence has not been so large as in 1950, and time has been saved by reducing the number of outside inspections.

Lyctus *Powder-post Beetles*

Investigations on Treatment of Timber in Stick. The failure of D.D.T. and benzene hexachloride, when applied in the form of fogs for the protection of stacks of timber during seasoning or storage, has been attributed to irregular distribution and variation in amount of insecticidal deposit. The results of experimental work during the period 1948-1950, described in the last Report, indicated however, that with improved methods of application an appreciable measure of control might be obtainable. With this object in view, further work

was started during the summer of 1951, using 5 per cent D.D.T. emulsion in water and 1 per cent of the gamma isomer of benzene hexachloride, made up from a water-dispersible powder, applied respectively to two stacks of English oak by a commercial type of fog applicator and using an extension hose to permit of greater coverage than could be obtained by the standard fogging treatment. For comparison, a third pile was treated with 2 per cent D.D.T. emulsion in water applied as a spray according to the recommendations in the Laboratory's Leaflet No. 43.

Provision was made for the removal of test samples and boards from all piles, including an untreated control, for exposure to attack by *Lyctus*. An estimate of the insecticidal deposit given by the various treatments was obtained by examination of filter papers inserted at different positions within the piles, the chemical analyses involved being kindly undertaken by the Fungicide and Insecticide Research Co-ordination Service of the Agricultural Research Council.

Natural infestation of the timber *in situ* during the past summer was supplemented by exposure of individual boards to attack by *L. brunneus* in wire gauze cages out-of-doors, the boards subsequently being returned to their original positions within the piles. A final comparison of the efficacy of the treatments must await the results of this part of the experiment and will not be available until the piles are dismantled for detailed examination during 1952. In the meantime, estimates of the amount and distribution of the insecticidal deposit suggest that again it is most irregular and unevenly distributed throughout the piles, varying in the case of D.D.T. from 64 to 0.1 microgrammes per 10 sq. cm. on the upper and lower surfaces of individual boards nearest the points of application of the insecticide: in other parts the deposit was as low as 0.05 microgrammes per 10 sq. cm. The amount of benzene hexachloride resulting from the treatments was too small for estimation.

The general indications from the results so far available confirm past work, suggesting that an adequate deposit of D.D.T. is obtained only at the sides of the piles easily accessible for treatment. Elsewhere, the amount is insufficient to prevent egg-laying by beetles in untreated timber after contact with treated wood for periods up to 24 hours.

Laboratory Tests of Insecticides. Investigations have been continued to ascertain the preservative value of preparations applied to oak sapwood by a one-minute dipping treatment for the prevention of attack by *Lyctus brunneus*. Two proprietary preparations based on pentachlorphenol and one consisting of an oil solution of benzene hexachloride have been tested. None of these preparations completely prevented egg-laying and hatching but larvae died shortly after emerging from eggs and before tunnelling extensively within the treated wood. Untreated controls were all severely infested.

Susceptibility of Veneers and Plywood to Attack. A problem which has become increasingly important during the year is that of infestation by powder-post beetles, chiefly *Lyctus* spp., in plywood and blockboard made up from certain tropical hardwoods, attack taking place either overseas or during storage in the United Kingdom. Past work in Australia and at this Laboratory has shown that at least temporary protection can be afforded by the addition of toxic materials to the adhesive. Benzene hexachloride has been found to be the most effective insecticide for this purpose but its use is at present not recommended in association with alkaline glues of the phenolic resin type, owing to the risk of its decomposition and loss of toxicity. D.D.T. has proved less satisfactory for the

purpose but in view of the urgency of the problem a further series of experiments to determine its value for the protection of plywood made up with a phenol formaldehyde adhesive has been started in co-operation with a firm manufacturing plywood in West Africa. For this work, test samples of plywood have been made up from specially selected veneers of starch content adequate for normal development of *Lyctus* larvae. Variations not only in the form of starch—sometimes granular, sometimes dispersed—in commercially available veneers but also in the colour reaction to the standard iodine-potassium iodide test for starch have raised interesting questions concerning the suitability for *Lyctus* attack of veneers differing in such respects and in changes in starch content that might take place during the different stages of veneer cutting, drying and manufacture into plywood. A small-scale test showed that veneers of obeche containing starch either in granular or dispersed form were equally suitable for normal development of the larvae. The need is, however, still apparent for a fuller investigation of all factors affecting the susceptibility of such plywood to insect attack and for the development of lasting means of preservation.

Insect Damage in Imported Timbers. The prevalence of pinhole borer and powder-post beetle damage in imported tropical hardwoods and plywood, especially from West Africa, continues to be a source of concern to importers and manufacturers and has again been the subject of numerous enquiries. The need has become increasingly evident for investigations on timber insects and staining fungi, with particular reference to the conditions governing susceptibility to and intensity of attack in logs, timber and plywood in the natural habitat of the insects. A revised memorandum summarizing the problem and including an outline programme of research has been prepared and is under consideration by the relevant committees of the Colonial Research Council. The widespread interest in the prevention of these defects in tropical timbers, to which attention has recently been given by French and Belgian Colonial authorities, is apparent from a request received during the year from an F.A.O. (United Nations) Forestry Mission to Mexico for information on experiments, and their results in British tropical countries, on the prevention of insect and fungal attack in timbers, with particular reference to those used in the veneer industry.

In the meantime, on the basis of existing knowledge, advice has been given to Forest Departments and others upon the value of insecticide treatments for the protection of logs. In this connexion, a number of logs of binuang from North Borneo, sent to the Laboratory for test, were treated by the Forest Department within a few hours of felling with different insecticides, which included a preparation of the creosote-type, benzene hexachloride applied as a water-dispersible dust, and a proprietary preparation containing pentachlorphenol and benzene hexachloride. Examination of the logs before and after conversion at Princes Risborough 3 months later showed that, whilst all treatments had reduced the extent of damage by pinhole borers as compared with the comparatively light attack in untreated controls, sufficient data were not available to enable any reliable conclusions to be drawn as to differences in efficiency of the materials used.

Routine examinations have been made of timbers reaching the Laboratory for general test and notes have been prepared on the presence of insect attack, and of starch content in relation to susceptibility to infestation by *Lyctus* powder-post beetles. These observations, together with other records of damage by

insects, have been summarized for inclusion in the Laboratory's leaflets on Commonwealth and other timbers.

The Common Furniture Beetle, Anobium punctatum

Investigations on this insect have been concerned chiefly with egg-laying and the effect of decay in timber upon the rate of larval development and upon other aspects of larval nutrition. A mass emergence of the insect took place in July from a quantity of New Zealand white pine removed from a building severely infested by the insect. The large number of beetles obtained supplemented existing information on emergence and egg-laying and enabled a series of general infestation experiments to be set up, including plywood, decayed oak sapwood, and other material for which insufficient insects were available in 1950. The artificial egg-laying surfaces described in last year's Report have proved satisfactory and have been used in all subsequent experimental work. An account of the technique, together with a summary of the Laboratory's records on egg-laying and hatching, with special reference to the effect of temperature and humidity, has been prepared[1].

The presence of decay in wood, with or without the addition of certain accessory food substances, has been found to accelerate larval development. For instance, examination of blocks of oak sapwood decayed by a white rot and impregnated with 1 per cent solutions of peptone, glucose or yeast, and subsequently exposed in 1950 to beetles for egg-laying, showed that during the 6 months of the experiment (which was unexpectedly curtailed by an incubator failure), the rate of larval growth had been accelerated by the presence of peptone. Glucose and yeast, on the other hand, had little effect compared with the rate of growth in untreated controls. This work is being repeated and amplified with a modified technique. Workers in Germany, investigating the value of insecticides and preservatives, have used a larval transfer method of introducing the larvae of the common furniture beetle into treated and untreated material. Whilst such a technique offers great advantages in dealing with an insect whose larval development is prolonged, the high mortaility which often results in the process is a serious handicap. A number of preliminary trials of different methods of transferring larvae have been made and in this connexion further experiments on the effect of decay and the presence of additional nutritive substances have been carried out. The results have confirmed the above indications of the value of peptone and suggest that yeast has a greater effect than hitherto was apparent.

Further work has been undertaken with composite blocks made up from Scots pine sapwood flour and and bone glue, in varying proportions. Accessory nutritional substances were added including peptone, yeast or glucose. The larval transfer technique was used but the results so far obtained have been unsatisfactory, possibly owing to the excessive growth of moulds or to some unsuitable factor in the constitution of the experimental blocks.

Further studies have been made of the sex characters of the pupae, and marked differences have been described, with a view to the preparation of a note for publication. Further information on the weights of pupating larvae has been obtained and individuals have been reared through the pupal stage to the adult, providing useful data in connexion with the growth and pupation of

[1] Bletchly, J. D. A Summary of Some Recent Work on Factors Affecting Egg-laying and Hatching in *Anobium punctatum* De G. *Proc. IX int. Congr. Ent.*, Amsterdam, 1951. (*In the press.*)

the insect. In the course of this work, a number of measurements of larval tunnels has been made and it was found that, under outdoor conditions, the average diameter of the tunnel made by the fully grown larva immediately before pupation is of the order of 1.72 mm. This figure has proved a useful guide for estimating larval size when examining experimental material in which mortality has been heavy.

Records have been maintained and information collected on the distribution of the insect and its comparative importance in different parts of the country. The co-operation of entomologists and others in Aberdeen, Dundee and Glasgow has been enlisted to supply local information not easily available at Princes Risborough.

Investigations with Insecticidal Smokes in Buildings

A brief account was given in the 1950 Report of the use of D.D.T. smoke liberated in a building for the control of wood-boring insects, and it was concluded that the value of the insecticide applied in this way was confined largely to the destruction of beetles present in the building at the time of treatment. In extension of this work, a further test was carried out in July 1951 using a commercially available benzene hexachloride smoke generator suitable for use in domestic premises. The smoke was liberated in a room of 650 cu. ft. capacity in which a number of test samples were placed to facilitate estimation of the amount and distribution of the insecticidal deposit. Some 250 common furniture beetles collected at random from various sources in the Laboratory and therefore of unknown age and egg-laying capacity were liberated in the room one hour before treatment. Collection and examination 17 hours later showed all to have been killed. Other batches of beetles of similar origin were introduced for 17 hours, 4 and 13 days after the smoke had been released. Although all were not killed, some residual effect remained and none of the insects laid eggs, although untreated control beetles from the same source survived and laid eggs. A residual effect was also obtained when beetles were placed in contact with treated surfaces up to 19 days after exposure to the smoke. Such an effect was largely confined to upper horizontal and vertical surfaces within the room.

In general, it may be concluded that a benzene hexachloride smoke liberated in a room during the emergence period of the common furniture beetle will destroy insects already present. A residual effect, dependent upon the orientation of different surfaces within the room, persists for an undetermined period, affecting the life and egg-laying of beetles maintaining contact with such surfaces. These conclusions suggest that for application as a means of control several such smoke treatments would be necessary during the emergence period of the common furniture beetle.

The Death-watch Beetle, Xestobium rufovillosum

Work on this insect has been confined to 21 inspections of buildings to advise on remedial and preventive treatments. This aspect of the Laboratory's work, in which churches and historic buildings are most frequently concerned, is of particular interest in relation to the need, widely expressed during the year in the press and elsewhere, for the development of some nation-wide scheme for the repair and maintenance of such buildings which are part of the Nation's heritage. For 20 years the services of an entomologist, experienced in inspection of buildings attacked by the death-watch beetle and other wood-boring insects,

have been available to church authorities, architects and others, and within the comparatively localized area covered by the diocese of Oxford alone, 40 inspections of the roofing timbers of churches have been carried out during the past 5 years. The demands on the time of the entomology staff of the Laboratory for this type of work cannot now be met without prejudice to the progress of its research programme, and it has become necessary to refuse requests for such inspections and reports. The Laboratory's long experience in this work has shown its value and endorses the need for its being taken over by some central organization adequately equipped and covering the country as a whole. Not the least important part of such a scheme, in so far as damage by insects is concerned, would be provision for regular inspection at intervals of, say, 8-10 years, in order to detect infestation in its early stages and to judge of the efficacy of past remedial treatments.

The value of such periodic examination was demonstrated during the year by observations on the death-watch beetle in Westminster Hall. During the recent renovations to the roofing timbers, following fire damage during the war, the opportunity was taken of determining the extent of activity by this insect, and it was recommended to the Ministry of Works that, as a means of judging continued activity, records be kept each spring over a period of years of the number of beetles found on the floor of the Hall. During April and May, 1950, a number of beetles was found in localized areas, which enabled their origin to be traced. The Laboratory assisted in the inspection of these areas, in which replacement of portions of timbers and further insecticide treatments were carried out.

Sirex *Wood-wasps*

The arrival in Australian ports early in 1951 of consignments of European softwoods severely infested by *Sirex* wood-wasps has had extensive repercussions in this country. *Sirex* spp. do not occur in Australia but are reported to have caused considerable trouble in New Zealand. Australian authorities have therefore been anxious to take every precaution to prevent introduction of these insects to their country. This Laboratory was approached during the year by the Division of Forest Products, Melbourne, to collect information on the habits and present economic status of *Sirex* as a pest in the United Kingdom. This involved discussions with entomologists at the Imperial Forestry Institute, Oxford, the Forestry Commission Research Station, Alice Holt, and at the British Museum (Natural History). A memorandum, including reports by these authorities, was prepared and despatched to Melbourne. In view of numerous enquiries received in this country concerning the elimination of timber showing damage by *Sirex*, particularly from packing case and crate manufacturers, and others exporting to Australia materials in which softwoods are used, a note has been published[1] on these insects, and how to recognize the type of damage they cause in converted timber.

The House Longhorn Beetle, Hylotrupes bajulus

It has been possible during the year to devote time to a study of this insect which has become of increasing importance in certain areas in the south of England[2] Attention has hitherto been drawn to the prevalence of the pest in a

[1] FISHER, R. C. A Note on *Sirex* Wood-wasps. *Timb. News*, 1951, **59** (2146), 332-333.

[2] FISHER, R. C. & HARRIS, E. C. A Note on the Status of the House Longhorn Beetle, *Hylotrupes bajulus*, in Great Britain. *Proc. VIII int. Congr. Ent.*, Stockholm, 1950, 767-69.

particular locality in Surrey, but for some years there have been indications from advisory and other work that neighbouring districts are likely also to be affected. A survey, on a small scale, of property in such an area was carried out during the year, and the results are of interest. For instance, examination of semi-detached houses in two roads revealed that in one, 8 out of 11 houses contained active infestation in the roofing timbers, whilst in the other, 15 out of 29 were similarly affected. A notable feature in the latter case was the extensive attack in fencing, ornamental woodwork, garden sheds, etc., even where infestation was absent in the roof of the properties concerned. The results of this limited survey are sufficient to indicate that in the district in question, infestation by the house longhorn beetle is as severe and probably as extensive as in the area in which widespread damage was first found in this country.

There is at present no evidence that, as recently found in South Africa, this longhorn beetle can breed in old stumps, logs or dead branches in pine woods in this country. The occurrence of the insect in buildings chiefly in pine-growing districts suggests, however, that this may yet prove to be so. Field work carried out in such areas during the year failed to detect the insect but an extension of the search is necessary.

In the course of advisory work, in which some 34 enquiries were directly concerned with this insect, 5 instances of infestation of imported packing cases were involved in parts of the country as widely separated as the south coast and Shropshire. It has not been possible to establish any instances of spread of attack from packing cases to structural timbers in buildings, but there is sufficient evidence now available to show that *Hylotrupes* can be widely distributed throughout the country by such a means. Records have been obtained during the year of attack by this insect in towns in the West Midlands, South Wales, and in London districts in which infestation has not previously been reported.

A stock of infested material taken from roofs of buildings has been made available to the Laboratory by a local authority in Surrey. A detailed examination of representative samples from this material has shown the larval population to be considerably smaller than might be expected in relation to the extent of damage caused. Some 50 beetles were obtained from this material stored in an insectary out-of-doors at the Laboratory. Emergence, which was usually confined to hot days, began on 19th July and continued intermittently until 11th September. It has been possible with these insects to make a start on experimental work on the biology and rate of development of the house longhorn beetle in this country. From 17 pairs, used to observe the habits, activity and length of life of the beetles, an average of 87 eggs per female was obtained under the natural conditions of temperature and humidity prevailing in the the laboratory. The incubation period of the eggs varied from 9-11 days at 25°-30°C. and 75 per cent relative humidity. Of 175 eggs maintained under laboratory conditions, only 4 per cent hatched, when central heating was turned on after an incubation period of 40 days. In general, there have been indications that egg mortality was high under all conditions of experiment, only 20 per cent hatching out of a total of 1,417 eggs laid. The first-stage larvae emerging from this material have been transferred to the sapwood of recently or partly seasoned Scots pine for investigations on their rate of growth under different atmospheric conditions.

Contact has again been maintained with local authorities in the infested areas and with the Ministry of Housing and Local Government with regard to the

distribution and control of the pest. A short course of instruction on how to recognize and deal with infestation was given at the Laboratory to representatives of local authorities near districts in which the insect has caused damage.

Advisory Work in Entomology

The types of enquiry have, in general, followed the same pattern as in recent years, the common furniture beetle being concerned more frequently than any other insect. The proportion of enquiries seeking information on its control remains fairly constant from year to year, at just over one-third of the annual totals. Most of those are the outcome of infestation of structural timbers and joinery work in buildings; in only a comparatively small number is furniture alone involved. The importance of the common furniture beetle in certain industries has come into prominence during the year by serious damage caused to wooden pattern blocks, usually of laminated structure with glued joints, and wooden printing rollers, used in the textile industry. The structure and conditions of storage of large numbers of hand-printing blocks, often of considerable age and value, held for long periods without being disturbed, favour widespread infestation by this insect. A comparable but less extensive problem has arisen in the hosiery industry where trouble has been experienced in bobbins of birch. In all these instances remedial treatments which might interfere with subsequent printing, dyeing or other manufacturing processes preclude the use of a liquid insecticide. Fumigation is generally the most practical remedy but has the disadvantage of not preventing re-infestation.

Of other insects, powder-post beetles and pinhole borers, particularly in tropical hardwoods, including plywood, have again been the subject of numerous enquiries. A number of cases of infestation by *Lyctus* in English oak flooring was noted, and an instance of severe attack in tile battens and other oak timbers in council houses, necessitating extensive re-roofing, led a Local Authority to ban this timber for further use as battens. Such an embargo on oak is an unfortunate result of the indiscriminate use of untreated sapwood, and is unjustifiable so far as heartwood is concerned, because it is immune from attack by *Lyctus* and is highly resistant to infestation by other insects and to decay.

Mention has already been made of further records, obtained in the course of advisory work, of the presence of living house longhorn beetles and their grubs in packing cases imported chiefly from the Mediterranean area. There has been an unusual number of enquiries concerning damage by another, but far less important, longhorn beetle of the species *Criocephalus ferus* in consignments of sawn, unseasoned French maritime pine reaching this country during the first half of the year. The prevalence of this damage is probably associated with the extensive forest fires of 1949 in south-west France. This insect is unimportant as a pest of seasoned timber and hitherto its presence has been of little or no concern to the timber importer and user. The opportunity of examining infested material was taken to make observations on the habits of fully grown larvae and on the emergence of the beetles[1].

Enquiries on wood-boring insects and their control dealt with by letter during the year amounted to 1,351. In addition to examination of buildings in the course of investigations on the house longhorn beetle, 28 inspections of property were carried out, mainly on behalf of architects, church, university, and municipal authorities.

[1] HARRIS, E. C. A Note on *Criocephalus ferus* Muls. (Col. Cerambycidae, Aseminae) in French Maritime Pine, *Pinus pinaster*. *Ent. mon. Mag.* (*In the press*).

CHEMISTRY

Research on Wood Analysis

The fundamental investigation of certain aspects of wood analysis which was begun in 1950 has been continued, and has led to important conclusions regarding the nature and amount of lignin present in wood. Ever since the early pioneer work of Cross and Bevan, wood chemists have sought a method of removing lignin from wood while leaving the remaining components as far as possible in their original condition. This objective is most nearly approached when acidified aqueous sodium chlorite is used under controlled conditions as the delignifying agent. By this means some 90 per cent of the total sulphuric acid lignin present in the cell wall can be removed without apparently affecting the polysaccharide fractions, and a residue can thus be isolated which, although contaminated with a few per cent of acid lignin, contains the total polysaccharide fraction of the wood. The amount of this residue, corrected for the small amount of acid lignin in it, represents the so-called " lignin-free holocellulose " content of the wood, and is in good numerical agreement with the difference between the total weight of extractive-free wood substance and the amount of acid lignin present in it (100—L, where L is the percentage of acid lignin). Recent work by Müller[1] and by Jayme and Finck[2] has indicated, however, that when wood is only partially delignified with sodium chlorite the amount of " lignin-free holocellulose " derived from it is appreciably greater than 100-L.

In order to ascertain the reason for this discrepancy, a detailed examination has been made of the progress of delignification of beech and spruce woods by means of buffered aqueous sodium chlorite. This involved treatment of samples of extractive-free beech and spruce sawdust with aqueous sodium chlorite, buffered at pH 6.3 with a phosphate buffer, at 50° and at 70°C. for varying periods of time, and analysis of the partially delignified wood residues and of the resulting chlorite liquors. It was found that until about 90 per cent of the acid lignin had been removed the loss in weight sustained by the wood as a whole was less than the apparent loss of acid lignin. Thus, a part of the lignin originally present in the wood and determinable as acid lignin by the 72 per cent sulphuric acid method has been modified or stabilized during the delignification process so that it can no longer be isolated as acid lignin.

To determine the total polysaccharide content of the partially delignified wood residues these were hydrolysed with sulphuric acid to reducing sugars and the latter were estimated by potentiometric titration with potassium ferri-cyanide using a modification of Hagedorn and Jensen's method. The results of these determinations indicated that the formation of the stabilized modification of lignin referred to above is not accompanied by any increase in the amount of reducing sugars formed on hydrolysis. This material is, therefore, a non-polysaccharide, and will be referred to as " modified lignin ".

A method has been evolved whereby the modified lignin can be isolated from the acid hydrolysates of partially delignified wood. If the 3 per cent sulphuric acid solution which is obtained in the normal lignin determination is passed through a ZeoKarb 215 ion-exchange column the modified lignin is retain-

[1] Müller, O. The Chemistry of Beechwood. Parts I-III. *Liebigs Ann.*, 1947, **558**, 81, 157, 164.

[2] Jayme, G. & Finck, F. The Polysaccharide Portion of Spruce Wood. *Cellulosechemie*, 1944, **22**, 102-114.

ed on the column while the sugars and other soluble material pass through. The column is washed with water until free from acid, then eluted with alcohol. This removes the modified lignin, which can be recovered by concentrating and precipitating with ether. The modified lignin isolated in this way from partially delignified beech wood was found on analysis to contain C 50.43, H 5.65, Cl 6.53, and OMe 14.60 per cent, and has the probable empirical formula $5(C_8H_9O_4.OCH_3.\frac{Cl_2}{5})$ (requires C 50.42, H 5.60, Cl 6.63, OMe 14.60). The ultra-violet and infra-red absorption spectra of the modified lignin are in accord with those previously reported for acid lignin, but the carbon and methoxyl contents are lower than those of beech acid lignin. The relatively low carbon content suggests that the modified lignin may be non-aromatic. The presence of a carbonyl group is indicated by the infra-red spectrum, and is confirmed by the ease with which modified lignin forms a 2:4-dinitrophenylhydrazone.

When acid lignin determinations are carried out on normal beech and spruce wood the amount of reducing sugars present in the filtrates is considerably smaller than that which would be expected if all of the material which is not recovered as acid lignin were polysaccharide. Both for the original wood and for the chlorited wood residues the amount of material unaccounted for is about 9 per cent of the original weight of the wood. It is therefore postulated that an acid-soluble modification of native lignin also exists in the original wood. In the case of beech wood 7.6 per cent of this material (on an original wood basis) has, in fact, been recovered by the use of ion-exchange columns. When the acid lignin filtrates are treated in this way they no longer give the Măule reaction (in the case of hardwoods) or the well-known ultra-violet spectrum attributed to lignin.

The investigations described in the preceding paragraphs formed the subject of two papers which were presented at Conferences in America in September 1951 and are referred to on page 49. A note on the isolation from wood of an acid-soluble form of lignin has been submitted for publication as a letter to the Editors of " Nature "[1].

The preparation from beechwood of a bulk sample of hemicellulose, substantially free from acid-soluble lignin, has been undertaken for constitutional studies in co-operation with Professor E. L. Hirst of Edinburgh University. In the course of this preparation some interesting observations on the action of alkali on beech wood were made. Cold 0.1 N caustic soda dissolves some 6 per cent of the wood substance, consisting of approximately equal quantities of acid-insoluble and acid-soluble lignin, with very little hemicellulose. When normal caustic soda is employed the amount dissolved is increased to 19 per cent, the increment consisting almost entirely of hemicellulose. The amount dissolved by 7N caustic soda is rather smaller (16 per cent). Thus, by extracting beech wood first with O.1N caustic soda and then with N caustic soda a fraction is obtained consisting of fairly pure hemicellulose, which can be further purified by precipitation in the usual way. A large batch of hemicellulose prepared in this way contained 81.4 per cent of xylan, 10.4 per cent of uronic acid, and about 1 per cent of lignin-like material. The amount of hemicellulose which can be extracted directly from beech wood by means of caustic soda is about 40 per cent of the total hemicellulose content of the wood. The remainder can only be removed after delignification by the Cross and Bevan or other method.

[1] McDonald, I. R. C. & Campbell, W. G. Acid-soluble Lignin. *Nature*, 1952, **169**, 33.

Extractives of "Rhodesian Teak" (Baikiaea plurijuga)

As mentioned briefly in the Report for 1950 a water- and alcohol-soluble amino-acid has been isolated from the extractives of "Rhodesian teak". The same substance has also been prepared by Professor F. E. King of Nottingham University, who has elucidated its constitution and named it " baikiain ". It has been found, however, that baikiain and certain of its derivatives, as prepared in this Laboratory, exhibit different physical properties from those found by Professor King for his preparations[1]. For example, there are considerable differences in the values for the specific rotations of the preparations made in the two laboratories as shown in Table 3.

TABLE 3

Substance	Specific Rotation at 20° C.	
	F.P.R.L.	Nottingham
Baikiain	—226.0°	—201.6°
Baikiain hydrochloride	—153.3°	— 90.1°*
N-Benzoyl baikiain	—100.2°	— 91.9°

*Subsequently amended by Prof. King to —134·8°.

An exchange of preparations with Professor King has confirmed the above differences, and it is thought that baikiain, as normally isolated, probably consists of a mixture of the two optical isomers, in which the laevorotatory form predominates in varying proportions. In an attempt to clarify the position L-baikiain has been completely racemised by boiling with 10 N caustic soda, and DL-baikiain hydrochloride isolated by neutralizing the alkaline solution with hydrochloric acid, evaporating the solution to dryness, and extracting the residue with boiling alcohol. The resolution of the racemate *via* the cinchonine salt was unsuccessful because baikiain does not readily combine with cinchonine, but by the addition of D-camphor-10-sulphonic acid to a solution of DL-baikiain hydrochloride in caustic soda, evaporation to dryness and extraction of the residue with chloroform to separate the product from sodium chloride, a suitable salt was obtained. The fractional crystallization of this salt from dioxane is now being attempted in order to prepare the pure dextro- and laevo- forms of baikiain.

Extractives of Muave Wood

This work was undertaken to answer enquiries from various firms who reported that dust from the wood appeared to be toxic to their workmen. The bark of this tree, and also of other species of *Erythrophleum*, is known to contain certain alkaloids, the amount and nature of which appear to be variable.

The wood under investigation, provided in the form of floor blocks, was converted into sawdust and tested for the presence of an alkaloid by steeping in ammonia, then extracting exhaustively with ether. From this extract material has been isolated in 0.04 per cent yield (based on the weight of wood), the solution of which in dilute hydrochloric acid gave precipitates with potassium tri-iodide,

[1] King, F. E., King, T. J. & Warwick, A. J. The Chemistry of Extractives from Hardwoods. Part III. Baikiain, an Amino-acid Present in *Baikiaea plurijuga*. *J. chem. Soc.*, 1950, 3590-3597.

potassium mercuric iodide, platinum chloride, picric acid, and phosphomolybdic acid. Each of these reagents is known to give a precipitate in the presence of alkaloids.

These results have been communicated to H.M. Medical Inspector of Factories, and further work on the extractives is being deferred in the meantime.

Extractives of Makoré (Mimusops heckelii)

In a preliminary study of the extractives present in the heartwood of makoré three products were isolated, but a full investigation of these has not yet been undertaken.

When makoré sawdust was extracted with hot alcohol and the extract concentrated, a light brown oil having a high boiling point separated on the surface and a small quantity of a light-coloured crystalline solid was deposited. The latter was separated by decantation and recrystallized from aqueous alcohol. It consisted of small pinkish crystals, very soluble in water, but nearly insoluble in alcohol, which reduced Fehling's solution only after hydrolysis with acid.

The alcoholic solution was then treated with excess of acetone, when a saponin (2.4 per cent on the dry weight of wood) separated and was purified by further treatment with acetone. On hydrolysis it yielded a mixture of sugars, provisionally identified by paper chromatography as xylose, rhamnose, and glucose, and two aglycone components. One of these crystallized well from methanol, had m. pt. 313-317° (decomp.), $\left[\alpha\right]_D^{23}$ + 59.5° in menthanol, equivalent weight (by titration with caustic soda) 483, and analysis corresponding with $C_{30}H_{48}O_5$. It is probably a hydroxy-triterpene acid. The second aglycone was a white solid, much more soluble in alcohol than the first, and was not characterized further.

The solution obtained on hydrolysis of the saponin was deep red and appeared from its colour changes to contain an anthocyanidin.

Deposit in a Dipterocarp

An interesting deposit found in a tree was received from a trade source. It consisted of a white wax-like solid which appeared to contain an oil in admixture, it had been removed from a shake in the heartwood of a dipterocarp.

The substance, after removal of the oil, was purified by repeated crystallization from methanol, and had m. pt. 161-162.5°, $\left[\alpha\right]_D^{20}$ + 59.2° (c, 0.90 in chloroform), and contained C 81.8, H 11.3 per cent ($C_{30}H_{50}O_2$ requires C 81.45, H 11.3 per cent). The substance was insoluble in water and petroleum ether, moderately soluble in methanol and ethanol, and very soluble in ether, chloroform, and acetone. It was unsaturated, and unaffected by boiling alcoholic potassium hydroxide. There is some indication that this substance may be a previously unknown triterpenoid alcohol.

The residues from crystallization of the above substance were dissolved in benzene-petroleum ether and chromatographed on a column of alumina. Elution with ether yielded two fractions, m. pt. 142-145° and 148-151°, while elution with acetone gave a further product, an oil, having refractive index 1.424. These fractions have not yet been studied further.

Deposit in Iroko Wood

A short paper has been published describing the occurrence and composition of a crystalline deposit found in iroko wood[1], and shown to consist of calcium malate.

Production of Fibreboards from Secondary Colonial Timbers

Although at the end of 1950 the major items of equipment for this project had all been installed, experimental work was still held up because certain necessary modifications to two of the machines, namely the chipper and the hydraulic press, had still not been made by the manufacturers. These modifications were completed in July, 1951, and an investigation into the possibility of making hardboards from wallaba wood from British Guiana has begun. In spite of the rather unpromising nature of wallaba, and of various difficulties in manipulation and technique which have been encountered, a series of hardboards having good properties has been made. The presence in wallaba of fibre with good board-making qualities has thus been demonstrated.

The first experiments on wallaba were carried out on old, seasoned stock (poles), which was the only material then available, but a log of wallaba was later procured and converted into pieces suitable for chipping. It was noticeable that much improved results were obtained with the green timber as compared with the old material, both in chipping and in the subsequent processing. The difference is probably partly owing to the effect of long exposure to air on the resin, which is very abundant in wallaba, rendering it less reactive towards chemicals.

The conversion of the wood into hardboard comprises the following operations:

Chipping. Wallaba wood, in pieces 4 in. × 3 in. × 2 ft., was converted, by passing through the specially designed chipper, into pulping chips of good quality in high yield, with only a very small proportion of dust.

Cooking. As a result of a series of cooking trials with various chemicals and with water alone, it was found that the most satisfactory results are obtained by cooking with sodium sulphite with a proportion of sodium carbonate or bicarbonate. By cooking for 2 hours at 170°C. with 10 per cent of sodium sulphite and 5 per cent of sodium bicarbonate on the dry weight of wood, the chips were sufficiently softened for subsequent mechanical defibration, although when chips from the dried wallaba poles were used the amount of sodium sulphite required to produce the same degree of softening was much larger.

Beating. The softened chips, after washing, were defibred mechanically in the beater with a wide clearance between the roll and bedplate. The resulting pulp could then be refined to any desired extent by further beating.

Sheet-formation. The pulp is formed into a thick, wet mat on the sheet-forming machine by withdrawing the water from it through a wire screen by means of a vacuum pump. Some initial difficulties in preparing uniform sheets have been overcome.

Pressing. The mat is transferred on its wire to a hot press where it is pressed,

[1] Farmer, R. H. & Campbell, W. G. The Composition and Origin of a Crystalline Deposit in Iroko Wood (*Chlorophora excelsa*, Benth & Hook. f.). *Emp. For. Rev.*, 1951, **30**, 64-65.

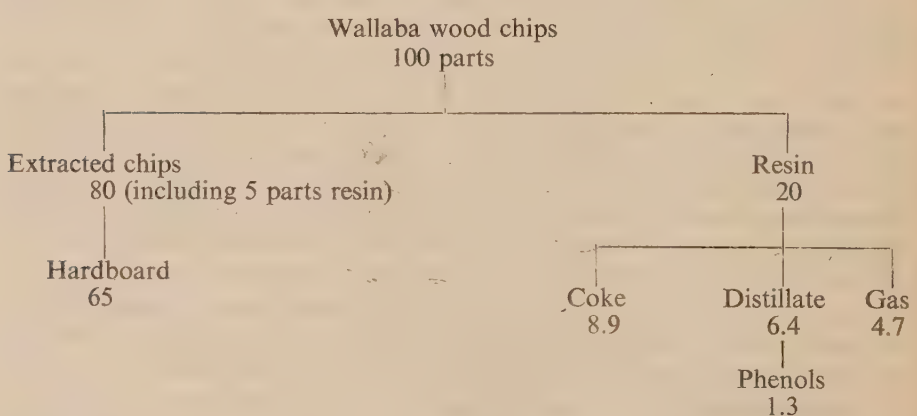
first to expel the water, and then to consolidate the material into a rigid board.

The variables which have been examined include the amount and nature of the cooking chemicals, the degree of beating, the pressing schedule (including the final pressure), and the effect of prior extraction of resin from the chips.

The properties of the experimental boards may be regarded as very satisfactory. Compared with commercial hardboards they are somewhat darker in colour and higher in density because of the nature of the starting material. Their strength properties (modulus of rupture 6,000-7,000 lb. per sq. in.) are considerably superior to those laid down for standard hardboards in British Standard Specification 1142. Their water absorption is somewhat high, but there is little doubt that this can be reduced by incorporation of size or by other known methods.

It was shown in 1948[1] that useful products, namely a high-grade metallurgical coke and a phenolic liquid are obtained if wallaba resin is subjected to destructive distillation at a high temperature. It was considered at that time that the manufacture of these products alone from wallaba wood would not be economically feasible, but the prospects are more favourable if, after extracting the resin from the wood and producing metallurgical coke and phenols from it, the wood residue can be used for production of hardboard. Experimental work on these lines is in progress, and Figure 4, in which a resin content of the original wood of 25 per cent (based on its dry weight) is assumed, indicates the approximate yields of products which may be expected from 100 parts (dry weight) of original wood. It has been found that about 80 per cent of the total resin in the wood can be removed by a single extraction of wallaba chips with alcohol.

FIG. 4



Visit to America

An extended visit to North America was made by the Officer-in-Charge, Chemistry Section, during August-October, 1951. This included attendance at the following Conferences and presentation at each of them of papers describing

[1] FARMER, R. H. & CAMPBELL, W. G. Production of a Metallurgical Coke from the Resin of Wallaba Wood. *J. Soc. chem. Ind.*, 1948, **67**, 233-234.

some aspects of the chemical work of the Laboratory [1-4]: Twelfth International Congress of Pure and Applied Chemistry, at New York; Fifth Meeting of the Sub-committee on Wood Chemistry of the Food and Agricultural Organization of the United Nations, at Appleton; International Pulp and Paper Symposium at Appleton; and a Symposium on the Fundamental Chemistry of Cellulose and Lignin at Montreal. The paper on the wood starches, presented jointly with Professor E. L. Hirst, F.R.S., represents the outcome of a lengthy piece of collaborative work in which many experimental difficulties have been successfully overcome in proving that constitutionally there is no essential difference between the wood starches and the starches of other plants, which are composed of approximately 20 per cent amylose and 80 per cent amylopectin. A full version of this joint work has subsequently been published in this country[5].

In the course of the American tour visits were made to the U.S. Forest Products Laboratory at Madison, Wisconsin, the Canadian Forest Products Laboratory at Ottawa, and several research institutes and pulp mills, and many discussions on matters of common interest took place.

Advisory Work in Chemistry

The number of enquiries answered by the Chemistry Section in 1951 was 289. The subject-matter of the enquiries covered the usual wide range, and included topics as varied as suitability of timbers for vats, factory roofs, laboratory floors, battery separators, cooling towers, bench tops, and many other applications where the wood may be exposed to the action of chemicals; stains and deposits of natural or chemical origin; various problems arising in the use of wood in conjunction with metals; extractives present in wood; and chemical utilization of wood and wood products.

Considerable attention has been given to a problem which arose in connexion with the use of wood flour as an ingredient of foundry sands. It is found that the quality of castings is improved if a small proportion (about 1 per cent) of wood flour is mixed with the foundry sand forming the mould, but that the presence of too large an excess may prove dangerous. As the wood flour is partly destroyed during the casting process a method was required for analysing the used sands in order to determine how much of the wood flour remained, and thus to calculate what fresh addition was required. It was not found possible to separate the wood particles quantitatively by physical methods from the other components of the sand (chiefly sand and coal dust), and a chemical method depending upon hydrolysis of the wood with sulphuric acid and determination of the resulting sugars titrimetrically was therefore developed. The following is an outline of the procedure. A dried sample of the sand is mixed with 72 per

[1] CAMPBELL, W. G., FRAHN, J. L., HIRST, E. L., PACKMAN, D. F. & PERCIVAL, E. G. V. The Chemistry of the Wood Starches. (Paper presented at *Twelfth International Congress of Pure and Applied Chemistry*, New York, 1951.)

[2] MCDONALD, I. R. C. & CAMPBELL, W. G. Some Observations on the Delignification of Wood by Sodium Chlorite in Buffered Aqueous Solution. (Paper presented at *Twelfth International Congress of Pure and Applied Chemistry*, New York, 1951.)

[3] MCDONALD, I. R. C. & CAMPBELL, W. G. Acid-soluble Lignin. (Paper presented at the *International Pulp and Paper Symposium*, Appleton, Wisconsin, and at the *Symposium on Chemistry of Cellulose and Lignin*, Montreal, 1951.)

[4] FARMER, R. H. & CAMPBELL, W. G. The Chemical Utilization of Tropical Hardwoods. (Paper presented at *Fifth Meeting of the Sub-committee on Wood Chemistry of F.A.O.*, Appleton, Wisconsin, 1951.)

[5] CAMPBELL, W. G., FRAHN, J. L., HIRST, E. L., PACKMAN, D. F. & PERCIVAL, E. G. V. Wood Starches. *J. chem. Soc.*, 1951, 3489-3498.

cent sulphuric acid and left to stand overnight. The acid is diluted to 3 per cent concentration and the mixture boiled for 2 hours, cooled, neutralized, and filtered. Measured portions of the resulting solution, which contains the sugars formed by hydrolysis of the wood, are titrated potentiometrically against an alkaline solution of potassium ferricyanide using two platinum electrodes and a polarising current. The ferricyanide solution is previously standardized against pure glucose, and the sugar equivalent (as glucose) of the wood flour as used in the foundry sand is determined in a parallel experiment. If the conditions of the titration, which is carried out at the boiling point, are adhered to, the results are sufficiently accurate and reproducible. Considerable interest in this analytical method has been shown by firms using foundry sand, and a number of samples of used sands have been submitted to the Laboratory for analysis.

In response to a request from the Printing, Packaging and Allied Trades Research Association, the preparation was undertaken of small samples of α-cellulose and of hemicellulose from wood for nutritional studies with uncommon insect species. Some sample fibreboards were also made from a semi-chemical hardwood pulp for trial as book-covers.

PHYSICS

Wood-water Relationships

Further experiments on scanning the hysteresis loop have been completed with four more samples, one of Sitka spruce and three of beech. The scanning was carried out in greater detail than before, four crossings of the loop being made on absorption and four on desorption. The results were similar to those of the previous experiments and showed only a slight difference between the behaviour of beech and spruce.

The effect of temperature on the hysteresis loop is now being studied, using two samples of spruce, two of beech, and one of fine beech flour, the latter being included to see if the isothermal of the wood flour differs from that of the solid wood.

This work on the effect of temperature is linked with that on the effect of temperature on the rigidity moduli of wood (see below), since a complete interpretation of the latter experiments requires a knowledge of the effect of temperature on moisture content of wood at constant relative humidity. However, the vacuum apparatus which is normally used for studies of the isothermal is unsuitable for use above about 50°C., and some measurements are therefore being made in the constant humidity and temperature oven which has been described in earlier reports. As in the vacuum apparatus, the quartz spring method of measurement is adopted, and some experiments have been made of the effect of temperature on the calibration of the quartz springs. It appears that the sensitivity of the springs decreases slightly with increasing temperature, but the resulting correction only becomes appreciable at temperatures approaching 100°C.

A new saturator has been constructed for the humidity oven, providing a much greater air flow than before. The components are also more easily accessible, and maintenance should be much easier.

Diffusion of Water Vapour through Wood

The experiments on the rate of uptake of water vapour by wood have been continued. The desorption experiment in which samples brought to equilibrium

with 90 per cent relative humidity were then exposed at 60 per cent relative humidity, has been completed and the samples have now been taken successively from 60 per cent to 30 per cent, to dryness, to 30 per cent and to 90 per cent relative humidity. The results so far available suggest that the theory of uptake of water based on the analogy with heat conduction is only an approximation, the discrepancies between theory and observation becoming particularly large for desorption at high moisture content.

Another method of studying water vapour movement is to subject discs of wood to a known relative humidity gradient and to measure the rate of transmission of water vapour by direct weighing. This method is now being applied to twelve selected species of varying structure and density. The rate at atmospheric pressure is being measured at temperatures from 20°C. to 40°C. in the three principal directions under a relative humidity difference of 100 per cent. The longitudinal direction is included for the first time, previous experiments having been confined to the radial and tangential directions.

Electrical Properties of Wood

(*a*) *Dielectric Constant and Loss Tangent.* The properties of wood which determine the heat developed during dielectric heating are the dielectric constant and the loss tangent. These two properties also govern the behaviour of an alternating current circuit containing wood as one of its elements as, for example, in some types of moisture meter. During the past year, measurements have been concluded in which the effect of moisture content, grain direction and frequency on dielectric constant and loss tangent have been studied for the following 12 species: quipo, western red cedar, Sitka spruce, cupressus, sycamore, sweet chestnut, Douglas fir, European larch, European oak, European ash, karri and wallaba. The latest results, at a moisture content of about 1 per cent, are interesting as some of the curves of loss tangent against frequency show indications of a maximum at a frequency of about 20 megacycles/sec .(Mc/s). These maxima have previously been reported by other workers, but had not so far been observed here. Their occurrence is apparently limited to very dry wood of certain species only.

Some typical results are given in Figure 5 A-D. The results at frequencies of 1 Mc/s and 10 Mc/s have been obtained by interpolation and those at 100 Mc/s by extrapolation, since the original measurements were not made at round frequencies and did not extend above about 50 Mc/s. Figure 5A refers to oak and Sitka spruce only, but Figure 5B refers to all the species at an average moisture content of 9 per cent. It is apparent from Figure 5B that dielectric constant is approximately proportional to density, and from Figure 5A that dielectric constant varies regularly, though not linearly, with moisture content and frequency.

There is no evidence that loss tangent is related to density and, in addition, the experimental errors associated with its measurement are much higher than those for dielectric constant. In view of these facts, the loss tangents of all the species at a given moisture content have been averaged and the average values are plotted against the moisture content in Figure 5C (radial direction) and Figure 5D (tangential direction). These figures show that the nature of the variation of loss tangent with moisture content depends markedly on the frequency. The values of the loss tangent are altogether much less predictable than those of dielectric constant; it would, in fact, be possible to estimate the dielectric constant

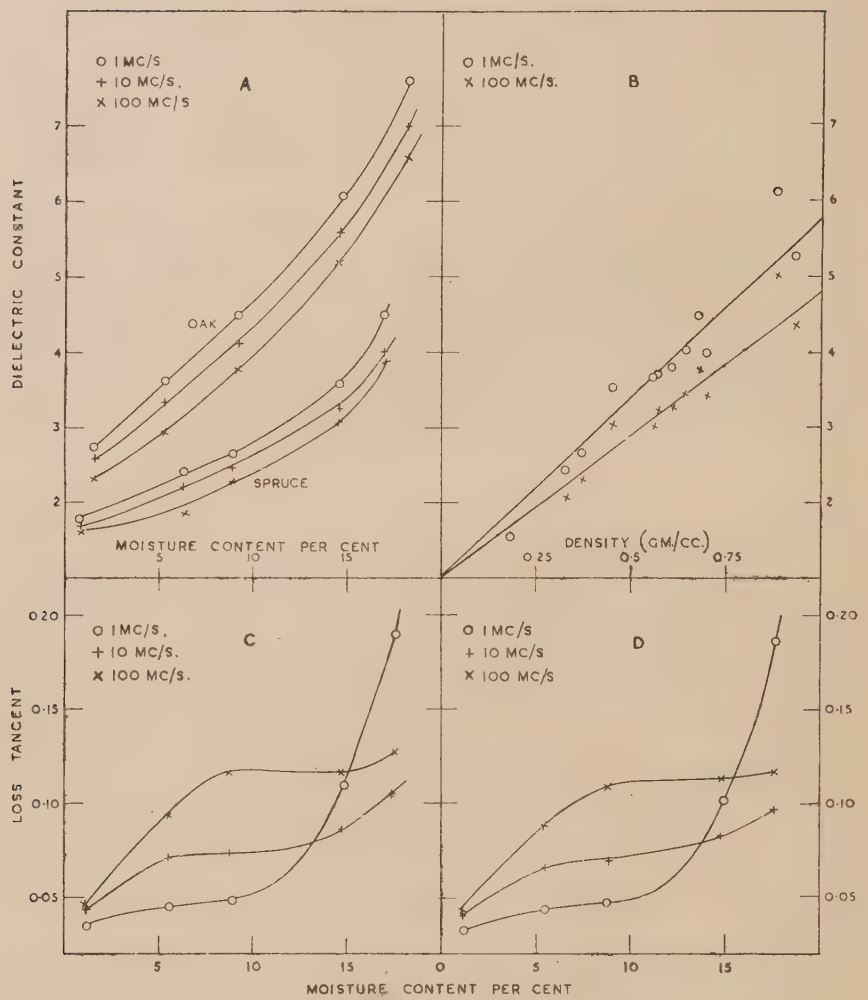


FIG. 5. DIELECTRIC PROPERTIES OF WOOD

of an unknown species fairly closely from the density, moisture content and frequency, but such an estimate would not be possible for loss tangent.

(*b*) *Piezo-electric Effects.* Some experiments have been made on the production of charges in wood by stress, in an attempt to verify a recent claim[1] that dry wood, cut at an angle to the grain, shows piezo-electric effects. The experiments were made with the wood subjected to bending and direct compressive stresses; in neither case was any definite indication of the development of piezo-electric charges observed, although the charges developed by quartz in direct compression were easily detected. These experiments were carried out in such a way as to observe the " direct " piezo-electric effect; if this effect exists, then the " converse " effect, observable as dimensional changes on applying an electric field, must also exist. The expected dimensional changes would in any case be

[1] BAZHENOV, V. A. & KONSTANTINOVA, V. P. Piezo-electric Properties of Wood. *Doklady. Akad. Nauk, U.S.S.R.*, 1950, **71**, 283.

very small and an optical interference apparatus has been used to measure them. No changes attributable to piezo-electric effects were in fact observed on wood, although the dimensional changes of quartz were measured without difficulty. It is concluded that piezo-electric effects in wood, if they exist at all, are extremely small, and work on this subject has been discontinued.

Elastic Properties of Wood

(*a*) *Effect of Temperature on Elastic Properties.* In continuation of the experiments on beech, described in last year's report, measurements have now been completed of the effect of temperature on the shear moduli (G) of oak in the three principal planes, the radial-tangential (RT), the tangential-longitudinal (TL), and the radial-longitudinal (RL). The results for oak show appreciably more scatter than those for beech, but satisfactory estimates of the change in shear moduli with temperature at constant relative humidity can nevertheless be obtained from them.

The mean temperature coefficient of rigidity modulus is defined by the equation

$$G_T = G_t \left[1-a\ (T-t)\right]$$

where a is the temperature coefficient and G_T, G_t are the shear moduli measured at temperatures T and t °C., T being the higher temperature of the two.

Figure 6 shows the mean temperature coefficients between 40°C. and 100°C. of both oak and beech, plotted against the relative humidity at which they were measured. There is no difference between the behaviour of the two species, or between the coefficients in the TL and RL planes. The coefficient in the transverse (RT) plane is higher at all humidities than in the other two planes, and all the coefficients increase rapidly with increasing humidity.

The use of a mean temperature coefficient as defined by the above equation implies that the shear moduli decreases linearly with temperature. There is some evidence that at humidities of 90 per cent and over, the relation between shear moduli and temperature for oak is not linear, but is curved in such a way that the shear moduli decrease more rapidly with temperature as the temperature increases. This effect, however, is not shown by any of the beech results, nor by the oak results below 90 per cent humidity.

(*b*) *The Deflection of Plywood Plates under Load.* The deflection of plates of afara, gaboon and maple plywoods cut at various angles to the grain and subjected to pure bending and pure twisting loads has been measured. These experiments were undertaken to check some points in the application of elastic theory to plywood and, in particular, the prediction that when a plywood plate cut at an angle to the grain is subjected either to pure bending or to pure twisting loads, the resultant distortion is a combination of bending and twisting deflection. This effect has been known qualitatively for some time, but the experiments provided the first opportunity to verify it quantitatively; the predicted and observed deflections agreed very closely.

Advisory Work in Physics

Enquiries on the following subjects have been answered by letter:— use of electrical resistance strain gauges on wood and plywood; thermal conductivity and expansion of wood; thermal and sound insulation of plywood; freezing

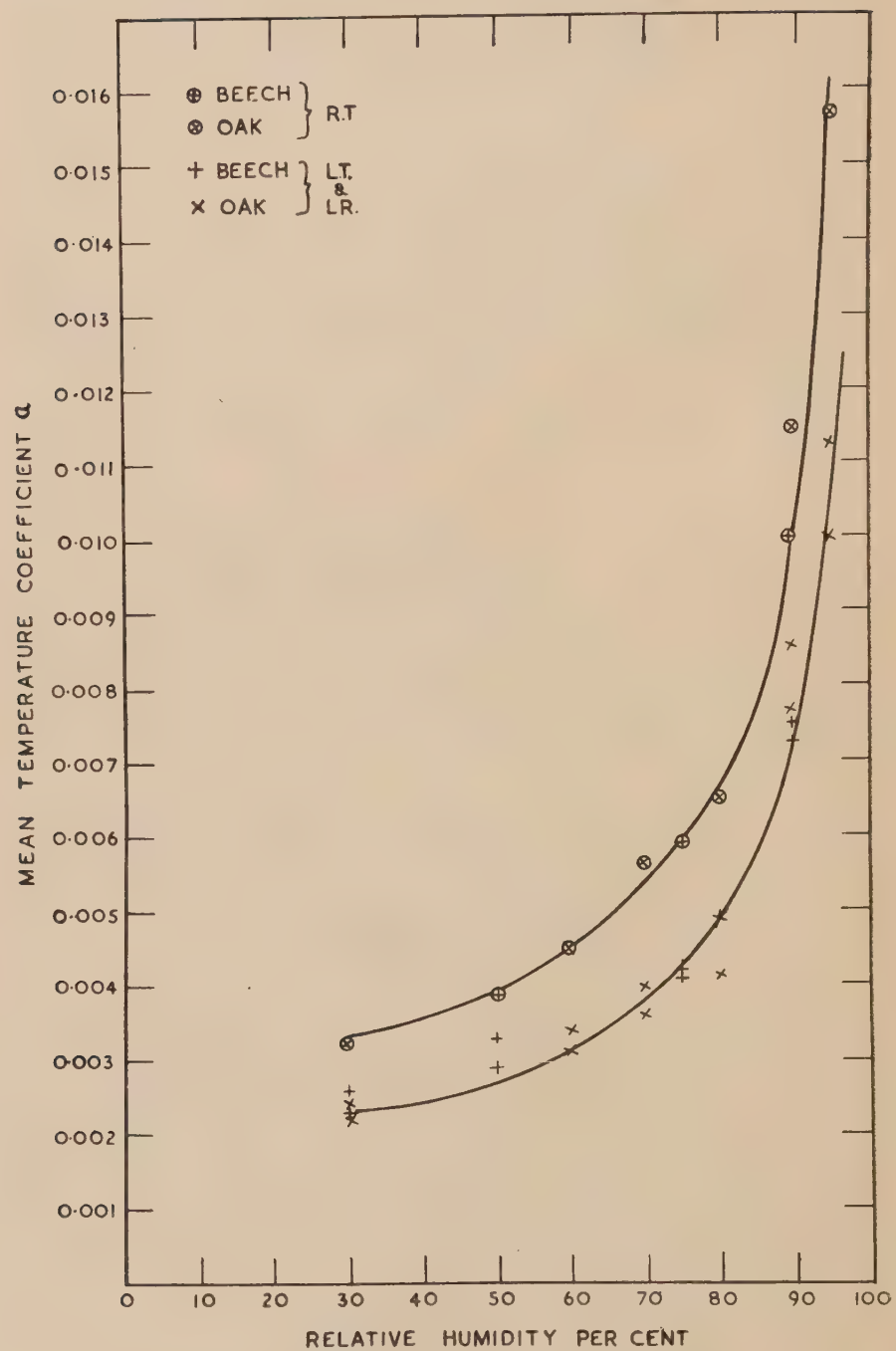


FIG. 6. [SHEAR MODULI OF OAK AND BEECH

point depression of wood at various moisture contents; use of ultrasonics and X-rays to detect faulty adhesion in glued joints; use of wood for musical instruments; dielectric properties of wood; effect of temperature on the relative humidity—moisture content relation of wood and other materials; Poisson's ratios of wood.

EXTERNAL RELATIONS

Selection and Procuring of Timbers for Test

The usual arrangements have been made with overseas Forest Departments for the supply for test of sound logs, from botanically identified trees. The chief timbers received during 1951 were:—

(1) afrormosia from the Gold Coast Forest Department
(2) adwea „ „ „ „ „ „
(3) brown sterculia from the Nigeria Forest Department
(4) wamara from the British Guiana Forest Department
(5) kurokai „ „ „ „ „ „
(6) crabwood „ „ „ „ „ „
(7) ' red birch ' from the Jamaica Forest Department
(8) hog plum „ „ „ „ „

Nos. (2), (6), (7) and (8) of the above were solely or mainly for plywood tests. The others were for full-scale general tests.

A supply of ramin logs from Sarawak was accepted from a commercial firm for general testing. Substantial supplies of this wood are being imported into the United Kingdom and interest a wide range of consumers in the furniture and joinery trades.

At the end of 1951, 20 species were in stock under or awaiting test.

Correspondence with the Forest Departments of Kenya, Tanganyika and Uganda has resulted in abandoning or postponing general tests on muhuhu and tali or mjembe, mentioned in the Annual Report for 1950, and accepting the suggestion from Uganda that their Forest Engineer should test sawn material of three other Uganda timbers, *Albizzia grandibracteata*, *Celtis soyauxii* and *Chrysophyllum albidum*, when seconded to this Laboratory in 1952.

Research on Pruning

The examination by knot dissection of pruned spruce logs supplied by the Forestry Commission in 1944 was completed. 567 knots in spruce from 7 districts were analysed on the critical data, which are the diameter of the parent stem before pruning and the diameter after healing of the side-branches responsible for the knots in the sawn timber obtainable from the log.

In all some 2,900 pruned knots in home-grown Sitka and Norway spruce have been dissected, from 76 trees and 29 localities. Measurements taken on over 1,200 of these knots, from 42 trees and 19 localities, have shown an average radial healing thickness of just under 0.5 in. of wood. Most of these branches were green when pruned. From this result and growth data from the Forest Research Station, Alice Holt, it appears that if a home-grown Sitka spruce tree is pruned to 26 ft. height, in three successive operations, to 6 ft., 16 ft., and 26 ft., as soon as the side-branches are dead to the height concerned, and if the healing wood over dead stubs is about the same in thickness as over green-pruned stubs, then the healed knotty core should have a maximum diameter of some 5.5 in.

(on the average site), at which size the core would form less than $\frac{1}{4}$ of the total volume of the same log if felled at a diameter of 13 in., when about 50-60 years old (growth quality class III, a common class for Sitka spruce in the United Kingdom as a whole). Over $\frac{3}{4}$ of the volume of such a log should be free of knots. A similar or even more favourable result may be expected from pruned Douglas fir, where pruning of green branches is safer than in spruce.

The dissection of the knots (approximately 60 per cent of Sitka and 40 per cent of Norway spruce) revealed no obviously diseased knots or wood; but from three of the localities the bark of the logs showed suspicious black weeping, similar to that found to be associated with attacks by *Stereum sanguinolentum* and other fungi in the wood of green-pruned spruces of both species at Lake Vrynwy and elsewhere in the United Kingdom. It is felt, therefore, that in line with experience in Germany and Sweden the green-pruning of spruce in the United Kingdom is dangerous in some localities and should normally be avoided throughout. Dead pruning appears to avoid much of the risk.

Such work as has been done on Douglas fir grown in the United Kingdom suggests that it may be green-pruned with safety. This agrees with the extensive experience of green-pruning various species of pine, outside the United Kingdom, without trouble from disease. Spruce is evidently more vulnerable than pine or Douglas fir.

If clear timber, free of knots, is to be produced quickly on a short rotation, in the United Kingdom, pruning is essential in the major softwoods, even allowing for what may prove possible by selection of fine branched races or strains. Where growth is fast and the wood is likely to be wanted in grades with few or no knots, pruning appears likely to pay.

Timber Quality in Relation to Silviculture

A start has been made on the collaborative scheme with the Forestry Commission of studying further the timber quality and utilization of the faster growing conifers now being planted on a very large scale in the United Kingdom. Sitka spruce and Japanese larch are two of the most important of these species.

A first trial lot of 20 Japanese larch trees, 46 years old and about 3 ft. in breast height girth, was bought from a private estate at Stourton, Wiltshire. These trees were selected because a permanent sample plot has been maintained and measured regularly in the crop since 1922. Thus the full silvicultural background was available. The trees were inspected before and after felling, and botanical material was collected from each tree, as a routine precaution—a precaution justified when expert examination of the cones showed that some trees of another Asiatic larch, *Larix potanini*, allied to *Larix leptolepis*, had been included in the Sample Plot of 1922 and the logs chosen for testing at Princes Risborough. Presumably the mixture occurred in the seed originally planted by the estate.

The plan to send 5 comparable trees to each of two well known private timber firms for commercial assessment was not carried out in this preliminary experiment because the estate could not spare more trees from the crop at this stage. Testing of specific gravity, strength, stability and other properties is now in progress.

Sawmill conversion, woodworking, kiln-seasoning, strength and natural durability data will, it is hoped, give an indication of the relation between timber

quality and silviculture in this first sample lot of Japanese larch to be handled under the new procedure.

Surveys of Main Timber-using Industries

Trade enquiries on tropical hardwoods for vehicle bodies have been numerous and show the continuing interest in this subject. It has been decided to re-visit some of the major firms early in 1952 and to review the provisional classification of about 100 timbers for lorry bodies, issued in 1948.

Further inquiries, visits and contacts in connexion with the furniture industry have been made, including liaison with the research staff of the Furniture Development Council. It was evident that price and the current availability of traditional timbers affected greatly the interest in any of the newer ones, and that import of properly graded stocks of sawn wood, such as Malaya and Sarawak sent to the United Kingdom in 1951, was one of the best ways of helping the furniture and other industries of the United Kingdom and the exporting interests of the producing countries.

The usual visits to specializing industrial firms, the timber trade, and forestry interests have been made during the year.

Instruction

The usual annual courses in utilization have been given. The 5-day course for forestry students from the Imperial Forestry Institute, Oxford, included 20 graduates on leave from the Colonies and 9 final year under-graduates. 32 final year forestry students from the universities of Aberdeen and Wales (Bangor) took their yearly course. Other regular courses included those for the instructors of the Timber Development Association (13 students); for Colonial Public Works Department officers (15 students); the Ministry of Works, Supplies Division (12 regional officers); and the Imperial College of Science (40 students). It is gratifying to note that the Colonial courses were attended by men from East and West Africa, Malaya, the Caribbean, Sarawak, Fiji, Cyprus, India, Pakistan and Burma (F.A.O. students). In addition facilities for study for longer periods were organized for students from Ceylon, British Hunduras and Pakistan. All of these visitors not only carry away what they have learnt of timber utilization but they also form valuable links between the Laboratory and the timber-producing countries in which they are stationed.

Special short courses were provided for officials of the Forestry Commission, the Furniture Development Council and the Timber Development Association, and at the request of the Ministry of Housing a special short course on the house longhorn beetle was arranged for building surveyors and sanitary inspectors from districts near affected areas in Surrey.

Six courses of instruction in seasoning were held during the year, and were attended by 52 trainees. Four trainees received special instruction in wood bending.

One-day visits were arranged for as many parties as staff time permitted. These were mainly from technical colleges, managers' associations and the like.

Lectures

Lectures on general and specific aspects of the Laboratory's work have been given in various parts of the country by senior members of staff. In January the Officer-in-Charge, Mycology, delivered an address on Dry Rot in Timber to

the Royal Society of Arts, for which a silver medal was subsequently awarded. It is interesting to recall that this Society was the first body in England to encourage the study of means for the prevention and cure of dry rot, having offered a prize for the most effective cure as early as 1784.

Exhibitions

The Travelling Exhibition on Dry Rot and Woodworm completed its first tour at the end of March and it was then decided to show it in another series of towns and cities. Additional panels illustrating other common defects and blemishes which are sometimes mistaken for dry rot were included. In nearly all the places visited the Exhibition has been well attended and considerable public interest has been shown.

To disseminate technical information on the availability and use of hardwoods for building and general purposes a comprehensive selection of timber samples was shown on the Department's stand at the Building Trades Exhibition at Olympia. A similar exhibit, which will include the newer hardwoods and also examples and a continuous film show on wood bending techniques is being prepared for the Furniture Exhibition at Earl's Court early in 1952.

During the year, other exhibits have included displays at the Festival Exhibition of Architecture at Poplar and at a number of local exhibitions organized by Medical Officers of Health and Sanitary Inspectors.

Advisory and Liaison Work

A total of 219 technical enquiries was answered by the Section during 1951, which is practically the same as in each of the previous two years. Most of these related to furniture, vehicles or other aspects of utilization.

F. Y. HENDERSON,
Director

FOREST PRODUCTS RESEARCH LABORATORY,
Princes Risborough,
Aylesbury, Bucks.

APPENDIX I

Staff at the Forest Products Research Laboratory

31*st December*, 1951

Director of Forest Products Research: F. Y. Henderson, C.B.E., D.Sc., D.I.C.

ADMINISTRATION

Assistant Director: S. T. C. Stillwell, O.B.E., B.Sc.
Senior Principal Scientific Officers: J. Bryan, M.Eng., A.M.Inst.C.E.;
K. St.G. Cartwright, M.A., D.I.C.
Higher Executive Officer: R. D. Weeks.
Executive Officer: Miss D. Lacey.

SECTION OF WOOD STRUCTURE

Principal Scientific Officers: B. J. Rendle, B.Sc., A.R.C.S. (Officer in Charge);
E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Scientific Officer: J. D. Brazier, B.Sc.
Experimental Officer: G. L. Franklin,
Temporary Assistant Experimental Officer: J. M. Chapman.

SECTION OF PHYSICS

Principal Scientific Officer: R. F. S. Hearmon, A.Inst.P. (Officer in Charge).
Experimental Officers: J. McC. Paton; J. N. Burcham.
Assistant Experimental Officer: E. H. Adams.

SECTION OF SEASONING

Principal Scientific Officer: W. C. Stevens, M.A., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officers: R. E. Hodge, A.I.Mech.E.; D. D. Johnston;
G. H. Pratt; N. Turner.
Experimental Officer: A. R. Dean.
Temporary Assistant Experimental Officer: T. R. Suckling.

SECTION OF TIMBER MECHANICS

Senior Principal Scientific Officer: J. Bryan, M.Eng., A.M.Inst.C.E. (Officer in Charge).
Principal Scientific Officers: F. H. Armstrong, M.Sc., A.M.I.Mech.E.;
J. Latham, B.Sc.
Scientific Officer: A. J. Comben, B.Sc.
Senior Experimental Officer: A. J. Foord.
Experimental Officer: J. G. Sunley, B.Sc.
Assistant Experimental Officers: G. R. Brock; W. T. Curry; Miss W. M. Fogerty.

SECTION OF WOOD PRESERVATION

Principal Scientific Officer: N. A. Richardson, B.Sc., A.R.I.C. (Officer in Charge).
Senior Experimental Officer: D. N. Smith.
Experimental Officer: L. W. Redding.
Assistant Experimental Officers: R. Cockcroft; Miss E. Lee; D. F. Purslow.

SECTION OF CHEMISTRY

Principal Scientific Officer: R. H. Farmer, B.A., B.Sc., D.Sc.(Tech.), F.R.I.C. (Officer in Charge).
Scientific Officer: Mrs. W. R. Carruthers, B.Sc.
Experimental Officers: D. F. Packman; L. C. Pinion, B.Sc.
Temporary Assistant Experimental Officer: I. R. C. McDonald, M.Sc., A.N.Z.I.C.

SECTION OF MYCOLOGY

Principal Scientific Officer: W. P. K. Findlay, D.Sc., A.R.C.S., D.I.C., A.I.C.T.A. (Officer in Charge).
Senior Scientific Officer: J. G. Savory, B.Sc.
Experimental Officer: E. C. Badcock.

SECTION OF ENTOMOLOGY

Principal Scientific Officer: R. C. Fisher, B.Sc., Ph.D. (Officer in Charge)
Senior Scientific Officer: J. D. Bletchly. B.A., B.Sc.
Temporary Scientific Officer: M. G. White, B.A.
Senior Experimental Officer: E. C. Harris.
Assistant Experimental Officer: Miss J. M. Taylor, B.Sc.

SECTION OF WOODWORKING

Principal Scientific Officer: P. Harris, B.Sc., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officer: R. Goodchild.
Experimental Officer: H. J. Endersby.

SECTION OF EXTERNAL RELATIONS

Principal Scientific Officer: C. W. Scott, O.B.E., D.F.C., B.Sc., Dip.For. (Officer in Charge).
Senior Experimental Officer: W. D. MacGregor, C.B.E., B.Sc.
Assistant Experimental Officers: Miss M. E. Smart, B.Sc.; Miss C. Webster.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer: R. A. G. Knight, B.Sc.(Eng.), M.I.Mech.E. (Officer in Charge).
Scientific Officer: J. F. S. Carruthers, B.Sc.
Senior Experimental Officers: L. S. Doman; R. J. Newall.
Assistant Experimental Officer: P. Burgess, B.Sc.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officer: C. J. N. McCracken, B.A., Dip.For. (Officer in Charge).
Experimental Officer: C. L. Stocker, B.A., Dip.For.
Assistant Experimental Officer: Miss E. M. M. Wood.

DRAWING OFFICE AND PHOTOGRAPHY

Senior Photographer: W. J. Baldwin.
Experimental Officer: E. A. Steel, A.I.Mech.E.

APPENDIX II

List of Publications Issued During 1951

A. Stationery Office Publications

Forest Products Research 1949.
Hardwoods for Building and General Purposes.

Bulletin:

No. 24. The Protection of Buildings and Timber against Termites. By W. D. MacGregor, C.B.E., B.Sc.

B. Other Publications

Leaflets:*

No. 10. An Overhead Internal Fan Kiln (The Double Stack Pattern). (*Revised edition*).
No. 39. Timber Decay and its Control. (*Revised edition*).
No. 40. The Preparation of Wood for Microscopic Examination. (*Revised edition*).
No. 45. Supplement No. 1. The Steam Bending Properties of Various Timbers.

Timber Leaflets:*

Introductory Leaflet.
Afzelia—*Afzelia* spp., principally *A. africana*, *A. bipindensis*, *A. caudata*, and *A. pachyloba* from West and Central Africa and some *A. quanzensis* from East Africa.
Albizzia—*Albizzia* spp., principally *A. ferruginea*, *A. gummifera* and *A. zygia*.
Antiaris—*Antiaris africana*.
Avodiré—*Turraeanthus africana* and *T. vignei*.
Ayan—*Distemonanthus benthamianus*.
Baromalli—*Catostemma commune*, *C. alstonii* and *C. fragrans*.
Celtis—*Celtis* spp., principally *C. adolphi-frederici*, *C. soyauxii* and *C. zenkeri*.
Curupay—*Piptadenia macrocarpa*.
Essia—*Combretodendron africanum*
Lapacho—*Tabebuia* spp.
Maho—*Sterculia pruriens*
Mubura—*Parinari excelsa*.
Ogea—*Daniellia ogea*.

Papers published in the Scientific and Technical Press:

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Resistance to Wear of Musine as Flooring. *T. c.* 258-259.
Resistance to Wear of Panga Panga as Flooring. *T. c.* 296-297.
Resistance to Wear of Afzelia as Flooring. *T. c.* 338-339.
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Resistance to Wear of Kokrodua as Flooring. *T. c.* 418-419.
The Resistance to Wear of Timber Flooring. *Building Research Congress, 1951. Papers Presented in Division 2*, 145-154.

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* Obtainable gratis from the Laboratory (Princes Risborough, Aylesbury, Bucks).

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FARMER, R. H. & CAMPBELL, W. G. The Composition and Origin of a Crystalline Deposit in Iroko Wood (*Chlorophora excelsa*, Benth. & Hook. f.). *Emp. For. Rev.*, 1951, **30**(1), 64-65.
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KNIGHT, R. A. G., DOMAN, L. S. & NEWALL, R. J. Durability Tests on Plywood Adhesives. *Wood*, 1951, **16**(6), 210-213.

LACEY, P. M. C. Strip Heating as Applied to Wood Joints. Paper read at the Aero Research Summer School, Cambridge, September, 1951.

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